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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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FOR BOILERS OF ALL TYPES.

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See page 101. 6485

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See Advertisement page 63. 6462

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—H. J. DAVIS & CO., Great Eastern Road, Stratford, E. 15.
Tel.: 736 and 737 Stratford.
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Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS and EVERY OTHER DESCRIPTION OF RAILWAY AND TRAMWAY ROLLING STOCK.
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See Illustrated Advt. in alternate issues. Od 3382

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BUILDERS of RAILWAY CARRIAGES & WAGONS.
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See half-page Advertisement, last and next week.

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FEED WATER HEATERS,
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See Full Page Advt., page 58, May 3.

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Forgings, Castings, Bars, Sheets, Wire, Tubes.
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See Full Page Advertisement May 31.

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WORK of all description undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work, moderate charges.—ROSSER & RUSSELL, LTD., Queen's Wharf, Hammersmith.
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Destroyers, Torpedo Boats, Yachts and Fast Boats. Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Centrifugals.
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Pott, Cassels & Williamson,
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See half-page Advertisement page 90, May 17.

The Manchester Steam Users' ASSOCIATION.

For the Prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. B. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 6661

The Manchester Steam Users' ASSOCIATION.

The ANNUAL GENERAL MEETING of the Members was held in the Board Room of the Association, at their offices, 9, Mount Street, Manchester, on Tuesday, June 4th, HAROLD LEE, Esq. (Manchester), President, in the Chair, when the following resolutions were adopted:—

Moved by the Chairman, seconded by EDWARD HOPKINSON, Esq., D.Sc. (Manchester), and resolved:—

"That the Report of the Committee of Management to the Subscribers be adopted."

Moved by Captain A. D. PROVAN (Mechanical Transport Dept., War Office, London), seconded by ARTHUR MORRIS, Esq. (Messrs. Andrew Knowles & Sons, Ltd., Pendlebury), and resolved:—

"That the thanks of the Association are due and are hereby presented to the Committee of Management for their past services, and that the following gentlemen be elected the Committee for the ensuing year, with power to add to their number:—

COMMITTEE OF MANAGEMENT:
HAROLD LEE, Esq., Manchester.
CHARLES HEATON, Esq., Bolton.
EDWARD HOPKINSON, Esq., D.Sc., Manchester.
HENRY WHITEHEAD, Esq., M.V.O., Bury.
The Hon. EDWARD COZENS-HARDY, St. Helens.
A. NORMAN DUGDALE, Esq., Blackburn.
J. H. MACMILLAN, Esq., Manchester."

Moved by CHARLES CROMPTON, Esq. (Messrs. John Crossley & Sons, Ltd., Halifax), seconded by J. P. CLAPHAM, Esq. (Bradford Dyers' Association, Ltd.), and resolved:—

"That Messrs. F.W. POPPLEWELL & SON, Chartered Accountants, Manchester, be appointed Auditors of the Association's accounts for 1918."

EDWARD A. BATEMAN, Secretary.
9, Mount Street, Albert Square, Manchester,
5th June, 1918. L 720

Inst. C.E., I. Mech.E., B.Sc., and all Engineering Examinations.

—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 6789

TENDERS.

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

OLD MATERIALS FOR SALE.

The Directors of the Midland Great Western Railway of Ireland Company are prepared to receive

Tenders for the Purchase of OLD MATERIALS.

Form of Tender, giving full particulars, can be obtained on application to the STOREKEEPER, General Stores Department, Broadstone Station, Dublin.

The Tenders must be posted in time to be received at Broadstone, on Tuesday, 18th June.

By Order,
PERCY A. HAY, Secretary.
Broadstone Station, Dublin.
4th June, 1918. L 716

LONDON COUNTY COUNCIL.

Tenders are Invited for the REMOVAL and DISPOSAL of ASHES

from the Council's Generating Station at East Greenwich, during the 12 calendar months commencing 1st August, 1918.

Particulars and forms of tender may be obtained at the Tramways Offices, 23, Belvedere Road, S.E. 1.

No Tender will be considered if received at the County Hall, Spring Gardens, S.W. 1, after Four p.m. on Monday, 17th June, 1918.

The Council does not bind itself to accept any Tender.

JAMES BIRD, L 684
Clerk of the London County Council.

APPOINTMENTS OPEN.

UNIVERSITY OF HONGKONG.

APPOINTMENTS IN THE FACULTY OF ENGINEERING.

The Council of the University

Require the Services of:—

(a) A PROFESSOR of Electrical Engineering. Salary £600 per annum, with quarters or an allowance of £100 per annum. Five years' agreement.

(b) Two LECTURERS in Civil and Mechanical Engineering. Salary £400 per annum, with quarters for residence. Five years' agreement. Passage money of £100.

The selected candidates will be required to take up their appointments as early as possible after September, 1918.

Applications should reach Messrs. FRESHFIELDS, CALDERON, SNELL & HIDER, 8, Queen Anne's Gate, Westminster, S.W., before Friday, June 28th, from whom further details of each appointment may be obtained. L 691

Capable, Well-educated Engineer,

with initiative and practical experience, to assist in important experiments with direct injection High Compression Oil Engines. Marine experience an advantage but not essential. Good prospects for the right man.

State full experience, age and salary required. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5339. L 615

Wanted, a Secretary for an

Engineering Association, some mechanical knowledge and secretarial experience required.—Address, stating past experience and salary required, L 699, Offices of ENGINEERING.

First-class Viewer, used to

testing Gears for High-class Motor Works. State wages required and full particulars of experience. No person already on Government work will be engaged.—Apply to the nearest EMPLOYMENT EXCHANGE, mentioning No. A 5390. L 634

A/S. CHRISTIANIA STAALVERK.

For construction of a new 80,000 tons Rolling Mill WANTS a First-class

Rolling Mill Engineer

who can take the position as Constructions Conductor and Manager for the rolling mill.

Applications requested to the direction of
A/S. CHRISTIANIA STAALVERK,
Bogt. 25, Christiania, Norway.
L 518

Engineer (Works) Wanted.

To be responsible, under Chief Engineer, for the running, upkeep and erection of large factory plant, including Boilers, Turbo Generators, large Gas Engines, Diesel Engines, &c. Must have had thoroughly technical and practical training and have held a similar position. Previous experience in a chemical factory an advantage. State fullest particulars, with copies of testimonials and salary required. (See War Notice.) — Address, L 538, Offices of ENGINEERING.

Wanted, Competent Man

for supervision of production at 8 in. Projectile Factory. Must be energetic, tactful, and experienced in handling female labour. Good salary. Anyone at present employed on Government work need not apply.—Apply, stating age, experience, and reference to your nearest EMPLOYMENT EXCHANGE, mentioning this paper and No. A 5363. L 589

Urgently Wanted, One Jig

and TOOL INSPECTOR for Tool Room, used to accurate work. No person engaged on Government work will be engaged.—Apply, A 5367, nearest EMPLOYMENT EXCHANGE. L 586

Wanted, Immediately, for

Midland firm engaged on Aero Engine work, first-class Jig and Tool INSPECTORS. State full particulars of experience. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5300. L 637

Wanted, Immediately, for

Midland firm engaged on Aero Engine work, first-class INSPECTORS for View Room. State full particulars of experience. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5197. L 633

Wanted, a Good Mechanical

ENGINEER, experienced in making Inventories and Valuations of Machinery. Applicants must give details of their experience and state salary required and if eligible or not for the Army.—Address, BOX 1881, WILLINGS, 125, Strand, London, W.C. 2. L 701

Supervising Engineer

REQUIRED for shore work, knowledge of ammonia and CO_2 refrigerating machinery essential, marine training preferred. Good position for the right man.—Reply, with copies of references, to BOX 652, T. B. BROWNE'S Advertising Offices, 163, Queen Victoria Street, E.C. 4. L 703

Assistant Required for Sub-

Contract Department of Aircraft Works, N.W. London. Good commercial engineering experience essential and a knowledge of woodwork desirable. No one now engaged on Government work or living more than 10 miles away need apply.—Address, stating full experience, age and salary required, L 705, Offices of ENGINEERING.

Wanted, Mechanical

ENGINEERS (Professional). Three required with general works experience and some commercial experience. A knowledge of works management and cost estimating advantageous. Salary £300 to £500, according to ability.—Apply, A.C.M.C., Room 130, Charing Cross Buildings, Villiers Street, London, W.C. L 688

Civil Engineering

DRAUGHTSMAN WANTED for all-round work. Ineligible for General Military Service.—State qualifications, experience and age to:—
SUPERINTENDING CIVIL ENGINEER,
H.M. Dockyard, Portsmouth.
L 634

A Large Aircraft Factory in

N.W. London, manufacturing machines of their own design, REQUIRE a number of Detail DRAUGHTSMEN with first-class aeronautical experience. Exceptional opportunities and permanent positions offered to suitable men. No one at present engaged on Government work or resident more than 10 miles away need write to BOX 490, SELLS, Ltd., 168, Fleet Street, E.C. 4. L 595

Draughtsmen for Aeronautical

work REQUIRED immediately for Midlands, previous knowledge desirable, but not essential. No one on Government work eligible.—Apply to your nearest EMPLOYMENT EXCHANGE, quoting reference No. A 5335. L 592

A Draughtsman is Required

by a large engineering works in the Midlands. Experience in mechanical or structural work is essential, and a knowledge of crane work is desirable. Age, salary required and full details of experience should be given in applications, which must be made through your nearest EMPLOYMENT EXCHANGE, quoting No. A. 5435. No one at present employed on Government work will be engaged. L 718

Wanted, Marine Engine Pipe

Arrangement DRAUGHTSMAN, must be thoroughly conversant with Boiler Room Installations for Destroyers and similar vessels. No one at present engaged on Government work need apply.—Reply, stating age, experience and wage required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and A 5456. L 702

Tool and Plant Draughtsmen

REQUIRED for urgent aero and motor work in progressive Midland works. Permanencies for live interested quick men with initiative and ability. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE mentioning No. A 5316. L 477

Draughtsmen Required in

important munition works. Those accustomed to furnace design preferred. No one on Government work or living more than 10 miles away will be engaged. State experience, age, and salary required.—Apply, BOX 134, Advertising Offices, 84, Queen Victoria St., London, E.C. 4. L 551

Draughtsman Required, with

good experience in design of Steelworks Machinery preferred, although applications from high-class men with other experience would be considered. No one already on Government work will be engaged.—State age, experience and salary required and when at liberty, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 4694 K 393

Capable Draughtsman Wanted

for Machine Tools by firm of Engineers in the London district. No person already engaged on Government work or resident more than 10 miles away will be engaged.—Apply, stating experience and salary, to L 517, Offices of ENGINEERING.

Draughtsmen.—Two Wanted,

by Munition Works on Tyneside, with experience in design of Jigs, Tools and Works Plant. No person already engaged on Government work need apply.—Reply, stating age, experience and wages required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 621.

Chief Draughtsman Wanted

for Controlled Establishment in West Riding of Yorkshire, manufacturing Petrol-Driven Commercial Motor Vehicles. Only those having previous first-class experience need apply, and no person already on Government work will be engaged.—Apply in first instance to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5341, and stating particulars of experience, age and salary expected. L 574

Wanted, for Urgent Govern-

ment work, South-West London district, JIG and TOOL DRAUGHTSMEN, accustomed to high-class, small, and accurate work.

No person already on Government work will be engaged.

Apply by letter, stating age, experience, and wages required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5337. L 576

Draughtsmen.—Several Good

Constructional DRAUGHTSMEN required to work on details of fabricated ships and other structural work. No one already employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5326. L 579

Draughtsman Required Im-

mediately, thoroughly experienced in Semi-Diesel Oil Engines, land and marine. Good salary will be paid to suitable man. No person already on Government work will be engaged.—Apply, stating age, experience, and salary required, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5300. L 584

Wanted, Experienced Jig

and TOOL DESIGNERS for large Electrical Works in the Midlands. Knowledge of Press Tools an advantage. Good salary and permanency to really capable men.—Apply, stating age, experience, and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this paper and No. A 4946. Nobody already employed on Government work will be engaged. L 498

Tool and Plant Draughtsmen

REQUIRED for urgent Aero and Motor work in progressive Midland works. Permanencies for live interested quick men with initiative and ability. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5316. L 636

Draughtsman Wanted, by

Firm of Gas Engineers and Contractors. Must be accustomed to gas plant and structural work, capable and energetic. No application from persons already employed on Government work will be considered. Full particulars of experience, age, and salary to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5394. L 639

Draughtsman Required to

TAKE CHARGE of Coal Washery Department. Experienced men only need apply.—Full particulars in the first place to K 624, Offices of ENGINEERING.

Leading Draughtsman Wanted

Manchester District. Government Contracts. Thorough experience furnace work essential, experience structural work an advantage.—Address, stating age, experience, and salary required, L 373, Offices of ENGINEERING.

Senior and Junior Draughts-

MEN REQUIRED, accustomed to the Design of Electrical Machinery. No one engaged on Government work or residing more than 10 miles away need apply.—State age, training, and experience and salary required to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 443.

Draughtsmen (12), Jig and

TOOL, urgently REQUIRED. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5318. L 501

Junior Draughtsman Required

on the Engineering Staff of a large Manufacturing Firm in the West of England.—Address, in the first place, stating age, experience and salary required, L 717, Offices of ENGINEERING.

Draughtsman Required for

LONDON, on work of National importance. One with experience in Flour and Starch Mill planning preferred. Liberal salary, exceptional prospects offered to efficient and capable man.—Write, giving details of previous experience, to "FLOUR," care of FROST SMITH & Co., 66, Finsbury Pavement, E.C. 2. L 660

Wanted Immediately, for

Midland firm engaged on Aero Engine work, Jig and Tool DRAUGHTSMAN as Checker. Good salary and prospect for suitable man. No person already on Government work will be engaged. Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5435. L 668

Draughtsman (Ineligible)

REQUIRED by a Controlled Establishment, to assist in the Hydraulic Press Department; must have Shop and Drawing Office experience. No person engaged on Government work will be engaged. Permanency for a reliable, capable man.—State, fully, experience, training, age and salary, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 709.

Wanted, First-class Draughts-

MAN, Blast Furnace and Iron and Steelwork experience, particularly Blast Furnace. No one already employed on Government work will be engaged.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 708.

Draughtsmen.—A Controlled

Establishment in the West Riding of Yorkshire, engaged on important high priority work, REQUIRE the SERVICES of a competent MAN, with first-class experience in General Engineering work; also experienced MAN for medium size machine tool work. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 4965. L 646

A Lady Tracer is also

REQUIRED. The above positions are permanent to reliable individuals. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 4965. L 646

Urgently Wanted, Three

Smart Jig and Tool DRAUGHTSMEN. Work is of a high-class quality with good post-war prospects to suitable men. No person already on Government work will be engaged.—Apply, A 5368, nearest EMPLOYMENT EXCHANGE. L 587

Tracers Required in impor-

tant munition works. Must have had previous experience. No one on Government work or living more than 10 miles away will be engaged. State age and salary required.—Apply, BOX 135, Advertising Offices, 84, Queen Victoria Street, London, E.C. 4. L 552

Wanted, Lady Assistant.

Must be well educated, understand elementary mathematics and be able to accurately file engineers' papers. Must have also fair knowledge of shorthand and typing. No one already employed on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, quoting this Journal and L 686.

Locomotive Draughtsman

REQUIRED, for Controlled Works in the North of England. No one already on Government work will be engaged.—Apply, stating age, salary and experience, to your nearest EMPLOYMENT EXCHANGE, quoting ENGINEERING and L 694.

Capable Mechanical Draughts-

MEN REQUIRED, for Aeronautical work in Government establishment 30 miles from London. Wages about £5 per week inclusive.—Address, giving full particulars, L 695, Offices of ENGINEERING.

Required, by Government

department near London, good mechanical or automobile engineer's DRAUGHTSMAN. Must be experienced and capable of working on own initiative. Write stating qualifications and salary required. No person already employed on Government work or living more than 10 miles away need apply.—Address, L 721, Offices of ENGINEERING.

Required. Thoroughly ex-

perienced LADY TRACER for Aircraft work. London District, one used to detail. No person resident more than 10 miles away or already on Government work will be taken. Reply stating age, experience, and salary required to L 726, Offices of ENGINEERING.

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Tool Room FOREMAN. Work is of a high-class quality with good post-war prospects to a suitable man. No person already on Government work will be engaged.—Apply, A 5309, nearest EMPLOYMENT EXCHANGE. L 588

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THE NEW TROLLHÄTTA CANAL.

(*Continued from page* 601.)

The lock gates and doors are worked by electric winches, placed in pits in the side masonry of the gate chambers in a concrete chamber entirely below ground-level, as shown in Fig. 28, Plate LVI *ante*. Details of the gear are illustrated in Figs. 42 and 43, subjoined. The lock gate is swung by a lever extension built up of plates and channels, as indicated. Near its free end this lever is supported by a roller which runs on a steel rail bent into the arc of a circle, as clearly shown in the plan view, Fig. 43. A pin at the end of the lever is coupled by a connecting rod to a long crankarm operated by the gearing shown in the two views. A spring interpolated in the connecting rod prevents the transmission of any dangerous shocks to the gearing should the gate meet with any obstruction when in motion. The gearing is intended to be driven by the motor shown, but, as will be seen, provision is also made for working the gate by hand should the necessity arise. The locks are also fitted with electrically-worked capstans, with bollards and mooring hooks, with windlasses for hoisting the ship's hawsers, with fender chains to protect the gates against collisions, with appliances for shutting off the locks when they are to be laid dry, and with ladders on the side walls. There is electric lighting on each side of each lock, and at the ends of the locks there are signalling masts. All the electric machinery except the capstans and the signalling lamps is controlled from operating boxes erected on the lock side; cables to and from the operating boxes and to the other gear are carried in tunnels under the lock at the upper and lower gate chambers. At the entrances to the locks there are towing paths and landing piers.

As already mentioned, single-plated gates were adopted. Such gates may be designed either on the arch or on the girder principle. The former are so constructed that when the gates are closed the plating carries its water load as an arch. If it were possible to ensure that the line of thrust always coincided with the neutral line of the plating a very light structure would suffice. As a matter of fact, however, a certain eccentricity of the line of thrust must be allowed for, and necessitates a considerable increase in the scantlings. As an example of gates of the arch type, we may mention the gates at the Mühlendamm lock at Berlin, the Dortmund-Ems Canal, the Oder-Spree Canal, the Berlin-Stettin Canal and the Erie Canal.

In the case of girder gates the structure resists the water pressure simply as a beam. Such gates may be framed either with horizontal or vertical girders, and in large gates secondary stiffeners may be necessary. When the horizontal system is adopted the girders rest directly on the main pivot and impact posts of the gate. When vertical stiffeners are used they are supported on heavy

Fig. 42.

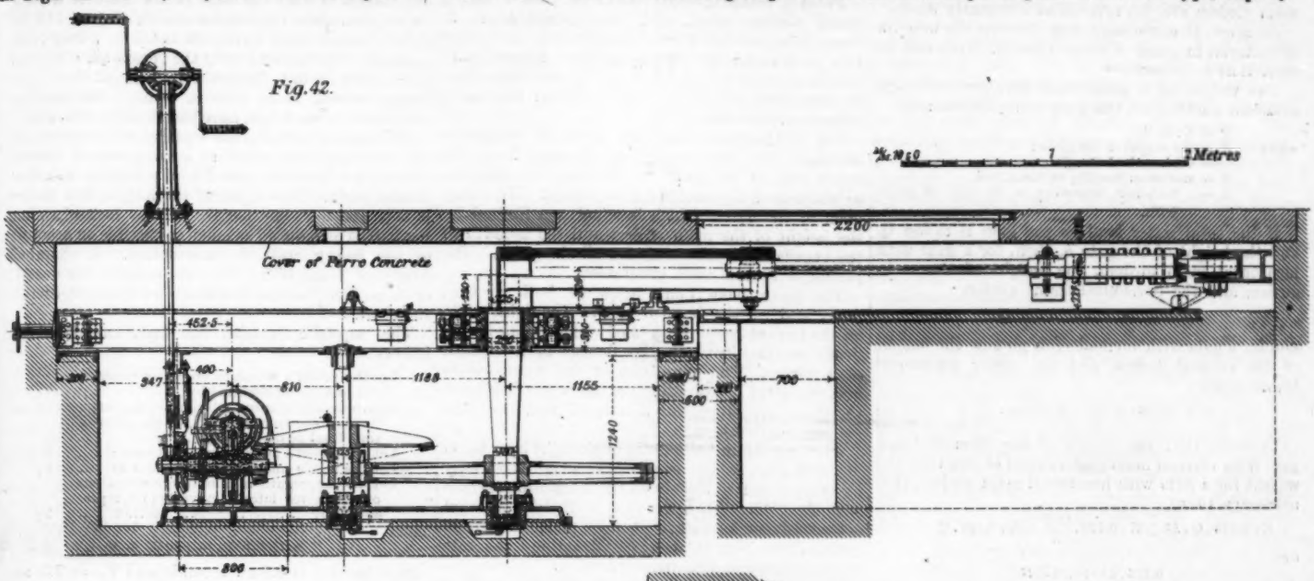
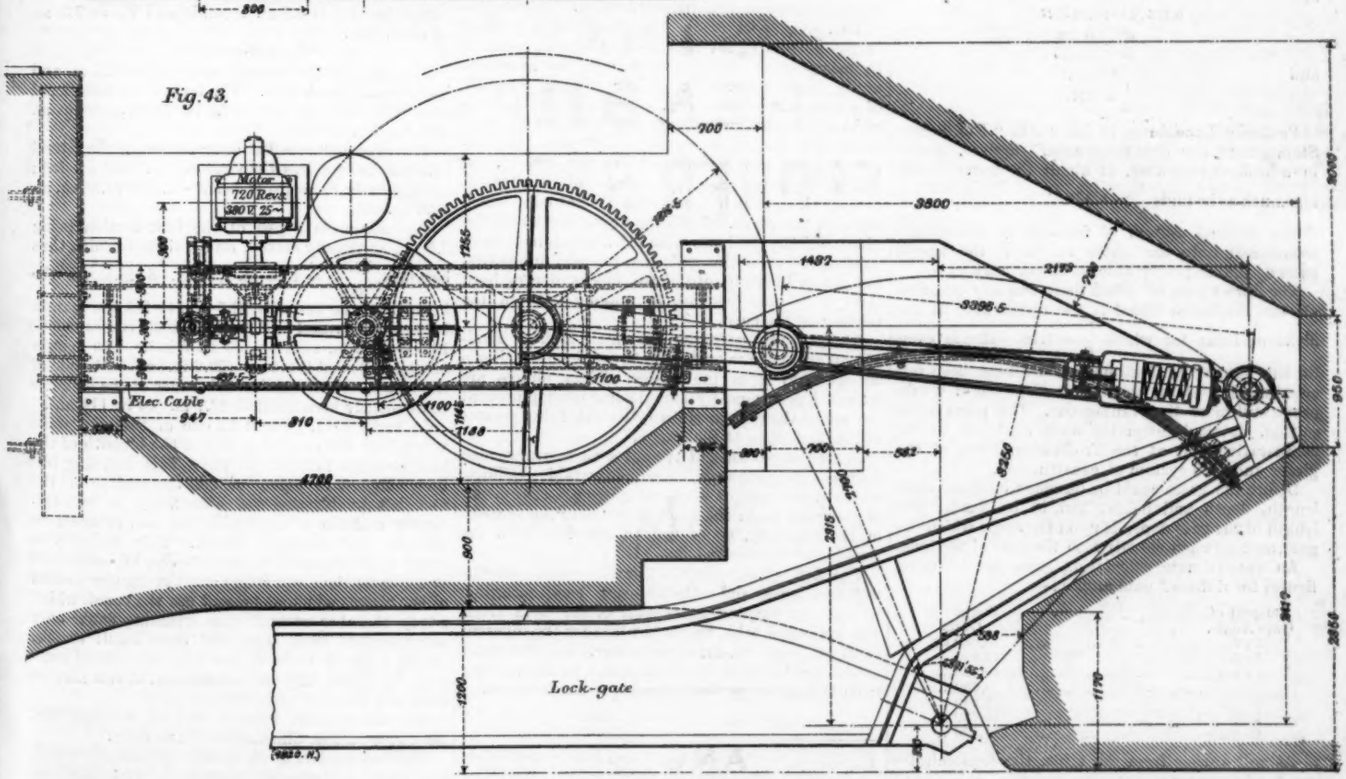


Fig. 43.



horizontal girders at top and bottom. Of gates with horizontal main girders constructed of late years we may mention the high gates used on the Kaiser Wilhelm Canal, the Elbe-Prase Canal and the Panama Canal.

As gates with vertical stiffeners may be mentioned the lower gates at Brunsbüttel on the Kaiser Wilhelm Canal (the length 40 per cent. larger than the height). Of girder gates those with horizontal main girders are the type most frequently used.

An approximate comparison between the weights of material in gates of these different types can be arrived at as follows :—

The weight of a girder can be expressed with sufficient accuracy for this purpose by the formula

$$P = K.M.l.$$

where P = the weight of the girder,
l = the length of the girder,
M = maximum bending moment, and
K = a coefficient depending on the type of girder used.

If the total water load on the gate is called Q, and the height of the gate h, then, for a gate with horizontal main girders, the weight of the main girders and the horizontal frame girders :

$$P = K.M.l = K.0.125.Q.h$$

and for a gate with vertical main girders the weight of the vertical girders and the upper horizontal frame girder :

$$= K.0.128.Q.h^2 + K.0.125.\frac{Q}{3}.h.$$

In order that the weight of the framing for a gate with vertical main girders shall be less than the weight for a gate with horizontal main girders, it is necessary that

$$K.0.128.Q.h^2 + K.0.125.\frac{Q.h}{3} < K.0.125.Q.h$$

or

$$0.128.h^2 < 0.0833\,h$$

$$\frac{h}{h^2} > \frac{0.128}{0.0833}$$

and

$$\frac{l}{h} > 1.24.$$

Professor Landsberg, in his work, "Die eiserne Stemmthore der Schiffschleusen," arrives, partly in a different manner, at about the same result, inasmuch as he finds $\frac{l}{h} > 1.225$.

The vertical system of framing is accordingly economical only for gates in which the length exceeds the height by at least 25 per cent.

The lowest gate of which there was any question at the Trollhätta Canal is the upper gate in the flight of locks for which $\frac{l}{h} = 1.18$. Hence even for this gate vertical framing would have been uneconomical, and for the others the system would prove still more disadvantageous. This point being settled, detailed estimates were made as to the comparative cost at the Trollhättan locks of the girder and arch system of construction.

Before the gates could be designed in detail their length, depth and height had to be fixed. The length of the gate depends upon the angle which the gate makes (when closed) with the axis of the lock.

An approximate calculation gave the following figures for different gate angles :—

Tangent of Gate Angle.	Weight of Gate.
1 : 7	15,040 kg.
1 : 5	11,350 ,,
1 : 3.8	10,960 ,,
1 : 3	9,690 ,,
1 : 2.5	9,350 ,,
1 : 2	10,770 ,,
1 : 1.6	12,570 ,,

As will appear from the table, the economically most advantageous gate construction is obtained with a gate angle having a tangent of 1 : 2.5, and this value was accordingly adopted. The increase or decrease of the masonry of the lock resulting from gates of different lengths was not only difficult to estimate, but also of slight importance, and it was not considered. For the girder gates the effective depth of the girder has been taken at one-eighth of the span, which has been found to be about the same as the most economical ratio. This height of the main beams has been adopted for all the gates, so as to secure more simplicity in the work. For the arch gates a thickness of 0.35 m. was assumed.

Three gates of each type were studied in detail and the comparative weights found to be as follow:

	Tons.
1. Girder gates without secondary stiffeners, about	6.80
2. Arch gates, about	6.45
3. Girder gates with vertical stiffeners, about	6.71

From a manufacturing point of view 1 and 2 stand about equal, and are preferable to 3. Since type number 1 was considered to be better able to resist such contingencies as impact from vessels in transit, it has been given the preference. It was decided to plate the up-stream face only, using metal 10 mm. thick.

For the transmission to the gates of the power necessary for their operation, an arm from the upper edge of the gates projects into the masonry, to which arm the machinery is coupled. The plan form of the gates, which is a polygon limited by the height of the main girders and the breadth of the standards, is the same for all the gates. The plating is 10 mm. thick in all cases.

The gates have joint strips at both vertical posts and at the bottom edge. The joint strip on the impact beam consists of a planed oak baulk, firmly secured between the flanges of a vertical plate girder. The joint strip of the post consists of a cast-steel I, extending up the whole height of the gate, and supporting a strip of hard steel (0.8 per cent. carbon).

At the bottom the gate is made tight by a beam of pitch-pine, which is given a certain elasticity by being mounted loosely on the bolts which secure it to the gate. When the gate is closed this beam is forced home against its stop by phosphor-bronze springs, the joint between the beam and the gate being made good by a strip of leather.

The pivot post of the gate rests on a bearing at the bottom of the lock, and is kept in position by means of a collar, anchored in the masonry, at its upper end. The lower bearing consists of a footplate of cast-iron, secured to the bottom of the lock and supporting a pivot plate of hard steel (0.6 per cent. carbon), 160 mm. in diameter and with a spherical upper surface, on which the gate rests by means of a shoe of cast steel, in which is inserted a steel cup, which rests on the pivot. Both the upper portion of the pivot and the steel cup were intended to have been hardened, but as this gave rise to some difficulties, the pivots bursting into pieces, blocks of very hard steel were used instead, in making both in the pivots and the cups.

At the upper gates for the single lock at Trollhättan there are in each gate two sluices, which can be operated from the bridge. These sluices are intended as a stand-by should some mishap prevent the use of the regular sluices, the risk being greater at this lock than at the others.

On the upper side of the gates there are wooden bridges or gangways, with adjustable railings, which stand upright when the gates are closed, but are lowered when the gates travel into the recesses in the masonry, so as not to interfere with the working of the traffic.

The Lift of the Locks.—The lift varies for the different locks, and also for each lock, according to the ever-varying water-level of the Göta river. The appended table shows the lifts for the different locks at high water, mean water, and low-water level, the locks being numbered I to VI starting from Brinkebergskulle and going towards Ström.

Height of Lift in Locks.

	Lock I.	Lock II.	Lock III.	Lock IV.	Lock V.	Lock VI.
	m.	m.	m.	m.	m.	m.
High water	6.30	8.50* 9.00† 9.50‡	7.83	7.88	7.74	5.15
Mean water	5.70	7.45* 7.95† 8.45‡	7.82	7.82	7.87	5.40
Low water	4.70	7.00* 7.50† 8.00‡	7.93	7.77	8.0	6.50

* At high water in the basin between Locks II and III.
† At mean water in the basin between Locks II and III.
‡ At low water in the basin between Locks II and III.

It will be seen from the foregoing table that the highest lift required is at lock II, where, with high water above and low water below the lock, it may amount to 9.5 m. (31 ft. 2 in.). In the flight of locks, however, the difference in the water-level of two neighbouring locks may amount to about 16 m. (52 ft. 6 in.) in certain circumstances, as when one is full and the other empty.

Type of Lock and Dimensions.—The principal dimensions of the locks have been fixed with a view to accommodate the largest vessels of 5 m. (16 ft. 5 in.) draught likely to use the canal for a long time to come. The dimensions of the vessels are : Depth, 5 m. (16 ft. 5 in.); breadth, 12.5 m. (41 ft.); and length overall, 87 m. (285 ft. 6 in.). The leading dimensions of each lock have been fixed as follows :—

The margin between the vessel and the bottom of the lock has been taken at a minimum of 0.5 m. (19¾ in.), which has been found adequate in other similar locks. The depth of the lock at low water is thus 5.5 m. The length of the lock chamber has had to be reduced as much as possible on account of the heavy cost of construction. A chamber length of 3 m. (10 ft.) more than that of the vessel, or 90 m. (295 ft. 3 in.) has therefore been considered sufficient.

The requisite breadth has been calculated as follows :—

Let the vessel's absolute speed on entering the lock be represented by ... ... V_a
Let the vessel's speed relative to the water flowing out from the lock at the sides of the vessel be denoted by ... ... V_r
Let the vessel's largest cross-section be ... F
Let the lock's smallest cross-section be ... F_1
Let the aggregate minimum cross-sections of the lower lateral culverts be represented by ... ... F_2

Then

$$V_a.F = (F_1 + F_2 - F)(V_r - V_a).$$

Supposing $V_a = 0.5$ m. seconds and $V_r = 1.5$ m. seconds, then

$$F_1 + F_2 = 1.5\,F.$$

The beam of the largest vessel equals 12.5 m. and its draught equals 5 m. The largest cross-sectional area $F = 0.9 \times 5 \times 12.5 = 56.25$ square m. (605 sq. ft.).

The aggregate smallest cross-section of the lateral culverts is not less than 9.5 sq. m. (102 sq. ft.); consequently $F_1 = 1.5 \times 56.25 - 9.5 = 74.88$ sq. m. (806 sq. ft.).

The minimum depth of the lock section being 5.5 m., as already stated, its requisite breadth thus becomes $\frac{74.88}{5.5} = 13.6$ m. (44 ft. 8 in.) As the breadth of the vessel is 12.5 m. (41 ft.) the margin between the vessel and the lock walls comes out at 13.6 — 12.5 m. = 1.1 m. (3 ft. 7 in.). The margin actually allowed is 0.6 m. (23.6 in.) on each side of the vessel, and the minimum breadth of the lock has consequently been fixed at 13.7 m. (44 ft. 11½ in.).

In locks I, II, IV and VI one of the side walls is put back 0.6 m. (2 ft.), so that the breadth of the lock becomes 14.3 m. (47 ft.). This widening has been adopted in places where the surface of the rock left by blasting has been found to be sufficiently uniform to constitute the wall of the lock without any masonry facing. This provides a wider lock chamber, so that it can accommodate at the same time four larger and two smaller vessels of the classes which at present use the canal, whilst a lock chamber without this widening could only accommodate three large and three small vessels. At the flight of locks it has been considered sufficient to widen only the middle lock, as this may be used as a meeting basin for vessels.

Our illustrations, Figs. 11 and 12, on page 598, *ante*, give further dimensions of the locks.

The Construction of the Locks.—As already stated the locks are situated entirely in rock, and are lined with concrete with or without granite facing. At locks I and II the lower edge of the wall is level with the bottom of the bottom channel or culvert, through which the lock is fed, as explained above. At the flight of locks, where this method, on account of the great height of the rock and the pronounced slope, would have entailed materially increased blasting, the bottom of the wall is placed as high as the existing conditions would permit, viz., immediately below the roof of the bottom chamber, and the side walls of this chamber abut

against the rock and are separate from the lock walls. The side walls of the locks are, as has been previously stated, of three different types, viz.: (*a*) an entirely free-standing or isolated wall; (*b*) a combined type, with the upper portion constructed as an isolated wall and the lower as a facing to the rock; and (*c*) in the form of piers. In addition, a complete wall of facing blocks is used in some instances. The adoption of these different types has depended upon the nature of the rock and its position. The isolated walls are used where the rock is friable, as at the eastern sides of locks I and V. The combined type, with the upper portion free or isolated, and the lower portion applied as a facing to the rock, has, in the first place, been adopted where the natural surface of the rock is below the level of the lock plane and the rock could be blasted almost vertically, and, secondly, where the rock was composed of such sloping strata that a facing wall against the rock the whole way up to the coping level would have been imperilled by blasting a possible future new lock at the side of the present lock. This combined type has principally been used on the west side of lock II and on a portion of the east side of lock I.

The pier construction, which consists of vertical piers, 2 m. broad and 5 m. apart, anchored to the rock, and joined at the top with a cover of reinforced concrete, has been used where the rock could be blasted to leave a vertical face and was so hard that no facing wall was needed; this was the case at locks I, III, IV and V, and on the east side of lock II.

Facing walls were used between the gate chamber and the pier masonry, where watertightness was required. The walls were keyed to the rock by means of anchor-irons.

The isolated or free standing walls are made of concrete, for the most part mixed in the proportion of 1 cement, 5 sand and 7 broken stone, with plums inserted, not exceeding 20 per cent. of volume. On the water side the walls are protected against impact of vessels or ice by granite from the upper edge down to from 0.7 to 0.8 m. (2 ft. 4 in. to 2 ft. 8 in.) below low-water level. The granite facing consists of rough hewn stones of 245 mm. (9½ in.) height, every third stone being a header, grouted with a mixture of 1 cement and 3 sand, and with 10 mm. (0.4 in.) joints. The joints were raked out to a depth of about 4 cm. (1.6 in.) and pointed with mortar of 1 cement and 1½ sand. On the top was placed a course of granite blocks, 0.5 m. (20 in.) thick, with their front side battered at 10:1, in order to guard against displacement by a vessel colliding against the top edge. At the back of the granite course is a watertight layer of concrete, mixed in the proportion of 1 : 2 : 2½ The water side of the wall below the granite facing is covered with a watertight layer of concrete 6 in. thick, mixed in the proportion 1 : 2 : 2½, with a smooth face 1½ in. thick. In locks I and II the vertical lower portion of the side walls, which also forms the side of the bottom channel, is covered with vitrified bricks, set in cement mortar to such a depth that the concrete and the bricks have an aggregate thickness of 350 mm. (14 in.). Underneath the wall on the clean rock is a layer 1 : 2 : 2½ concrete, on which, again, rests a layer of 1 : 3 : 5 concrete 20 in. thick. On this the wall is laid in a mixture of 1 : 5 : 7. At the back of the wall is also a watertight layer of concrete 1 : 2 : 2½, carried somewhat above the high-water level likely to occur below the lock. The upper portion of the back of the wall is smoothed and coated with asphalt down to 2 m. below coping level. The top of the wall is treated in the same way and afterwards covered with gravel. The masonry of the isolated wall is attached to the rock by means of 25 mm. (1 in.) anchor bars, spaced 1.5 m. (5 ft.) apart and let about 1 m. (3 ft. 4 in.) into the rock.

The piers and facing masonry are, in the main, constructed on the same plan as that described above, with the difference, however, that the bulk of the facing walls has been laid in a mixture of 1 : 3 : 5, and as the side of the wall towards the rock is drained, no special watertight layer has been adopted there. The facing walls are attached to the rock by iron anchors, as are in some places the isolated walls. In the combined type of masonry at lock I, where the lower facing wall cannot be drained, the concrete is reinforced to support water pressure against the back of the wall.

The walls, whether isolated or combined, are built as monoliths, generally in 10 m. (33 ft.) lengths. The monoliths which constitute the connection between the gate chamber and the pier masonry are made 6 to 7 m. long. On the sides against the pier masonry they are made fast to the rock by means of a vertical rib projecting into a groove in the rock, the object of this arrangement being to prevent the water from making its way behind the masonry. The monolith in question is not rigidly connected to the gate-chamber masonry. The use of a rib and a groove at the gate chamber itself would hardly have been feasible on account of the expansion and contraction to which the gate-chamber masonry is subjected under changes of temperature.

The gate chamber has been designed to suit the varied manœuvring appliances, &c., which are installed there. Thus there are recesses in the sides of the lock, into which the gates are swung when opened; further, there are the culverts, shafts for sluices and closing appliances, machinery chambers for the gate windlasses for sluices and fender chains, and cable shafts. In the bottom masonry there are races on which the gates move, cable tunnels connected with the cable shafts in the side walls, and underneath the gate-chamber bottom at the upper gate chamber (except for lock II) a sump into which the culverts open.

The walls of the gate chamber are built in the same general way as the side walls, the bulk of concrete in the proportion of 1 : 5 : 7, with a watertight layer along the sides and bottom in 1 : 2 : 2½ and 1 : 3 : 5. The sides are likewise faced with granite of the same dimensions as in the intermediate walls, down to 0.7 to 0.8 m. (2 ft. 4 in. to 2 ft. 8 in.) below low-water level, in addition to which all corners are faced with larger stones, 0.5 m. (20 in.) thick; the facing in the gate recess has vertical sides, there being no fear of any vessel colliding against it. The walls of the culverts and the sumps are faced with blue brick, in addition to which all the corners and all the grooves for sluices and closing appliances are faced with granite. The upper side of the gate chamber is set with small paving stones, 7 to 10 cm. (2¾ to 4 in.) square and 3 to 4 cm. (1¼ to 1½ in.) thick, on the roof over the machinery chambers, and 7 to 10 cm. thick in other places. On the machinery chamber roofs the stones are laid on a layer of asphalt, 1 cm. (0.4 in.) thick, in addition to which the joints are pointed with asphalt. The gate-chamber concrete is reinforced against changes of temperature by 14 longitudinal iron rods of 20 mm. diameter inserted in the thin wall between the gate machinery chambers and the gate recess. In addition, all the thin walls between the valve shafts and the closing gear shafts are reinforced so as to enable them better to resist water pressure. The lower western gate chamber of lock V is specially reinforced to withstand the pressure from the lock gate.

The bottom of the lock chambers I, II, III, IV and V simply consists of a levelling layer of concrete, about 150 mm. (6 in.) thick, laid in slabs about 2 m. (6 ft. 7 in.) square, of a mixture of 1 : 3 : 5, with an upper layer of 70 mm. (2¾ in.) of a mixture of 1 : 2 : 2½, on the top of which, again, is 1½ in. of cement mortar for wearing purposes. To prevent the slabs from being raised from the rock by water pressure from below, they are anchored by four iron stays 1 in. thick, in addition to which drainage has been adopted where considered necessary.

Further to avoid pressure being exerted behind the walls by ice or water, each monolith is drained separately, the system consisting of a number of closely placed small pipes which collect the water penetrating into the concrete, and lead it to a collecting pipe. This collecting pipe is joined to drains of larger dimensions in the sides of the locks, proceeding from the upper gate chamber to the lower and opening out into the basin below the lock. This main drain is only provided on that side of the lock which is continuous. The pier construction, on the other side, is not drained. In the side walls, facing the water, the arrangement for drainage consists of vertical pipes of 50 mm. (2 in.) diameter, at 0.5 m. apart and 0.7 m. (2 ft. 4 in.) from the outer side of the wall. These pipes deliver into a 100-mm. (4 in.) collecting pipe, located immediately above the lower high-water level in the lock, whilst the tops of the pipes are connected by means of a longitudinal air channel, formed in the concrete 8 in. above the high-water level, and communicating with the outer air through iron gas-pipes. Drainage for relieving the outer water pressure beneath and behind the wall, at lock I, is confined to a well, 0.6 m. (2 ft.) in diameter and 0.9 m. (3 ft.) high, at the back of the eastern side wall. This is designed to lead away the water collecting in the filling behind the wall.

The masonry of the gate chambers is drained on the same plan as are the side walls. The main lines consist of 300-mm. (12-in.) cement pipes, passing through the gate chamber and intermediate masonry, parallel with the direction of the lock and at a distance of 1.8 to 1.9 m. from the outer edge of the wall, according to the space available at the side of the valve shaft. At the upper and lower ends of the main, line shafts for cleaning purposes, which will allow a man to descend, are constructed, their breadth varying from 0.6 to 0.9 m. (2 ft. to 3 ft.), and as they ascend to the footway level, they are provided with covers of cast-iron. The outlet drain from the lower well to the canal basin delivers beneath the lower water-level, so as to prevent the outlet opening from freezing. On the main pipe lines passing through the joints of the monoliths there are sockets of cast-iron at the ends of the pipes in each monolith. At the upper gate chambers in the flight of locks there are flushing valves, by means of which the main pipe lines can be put under pressure from water-levels above the locks and thus effectually flushed out. Such valves have not been adopted at locks I and II, the pipes here being flushed out by pumping water into the upper wells. At lock II a valve has been placed at the middle of the upper gate sill for washing down the lower drainage system.

To prevent water from the lock from penetrating underneath the side walls, and water from the basins above the locks making its way into the lock beneath the upper gate-chamber masonry, the lock chambers, at the inner sides, and the gate-chamber masonry along the bottom contour facing the upper water basin, are constructed with a tongue of concrete, where such is considered requisite, sunk into the rock bottom, about 1 m. deep and 1 m. broad, the concrete being mixed in the proportion 1 : 2 : 2½. The upper tongues extend into the rock at the side of the lock, as at lock II, or into a dam adjoining the lock, as at lock I.

The walls of each lock, when standing clear of the rock, have been designed for the following loads:—

1. The lock emptied and the wall exposed to earth pressure from behind up to the upper edge of the wall and to water pressure from below and from behind corresponding with the high-water level below the lock.

2. The lock full of water to high-water level and the earth fill behind the wall removed.

In calculating the earth pressure the following coefficients have been used:—

	Above Water.	Below Water.
The natural angle of repose of the earth fill	45 deg.	30 deg.
The frictional angle ...	30 „	22.5 „
Specific gravity	1.8	1.2

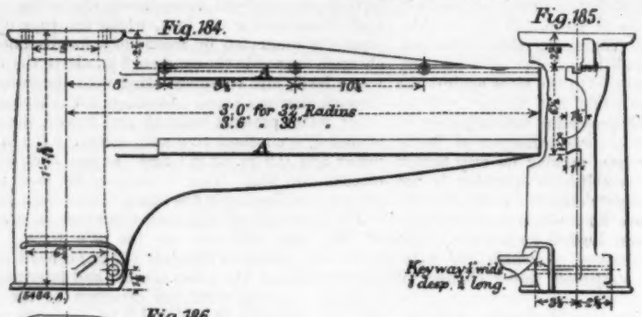
The greatest stresses at the undersides of the walls arise under load condition No. 1, when the lock is empty and the walls are filled up behind. The highest calculated stresses have been limited to about 20 kg. per square centimetre (284 lb. per square inch.).

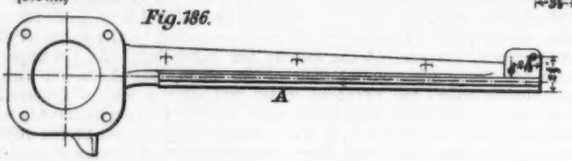
(To be continued.)

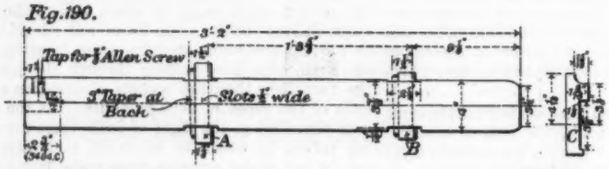
ACTIVE NITROGEN.

The expression "activated elements" is about as old as this century. It was adopted to indicate that some elements like nitrogen, inert or apparently passive under ordinary conditions, become active under certain, not understood, conditions. Active nitrogen has particularly been studied for nearly ten years by the Hon. R. J. Strutt, Professor of Physics at the Royal College of Science, South Kensington,

TEMPLETS, JIGS AND FIXTURES.



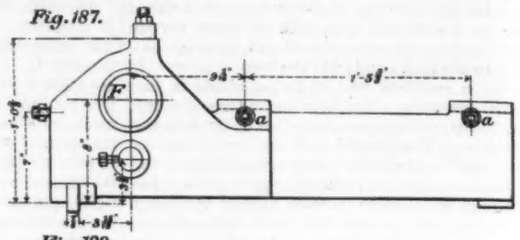


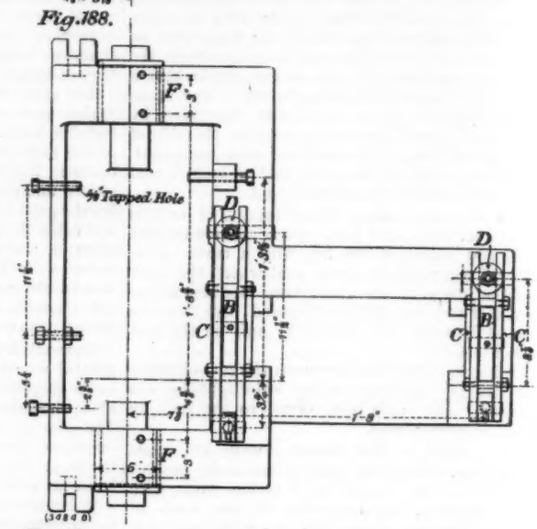


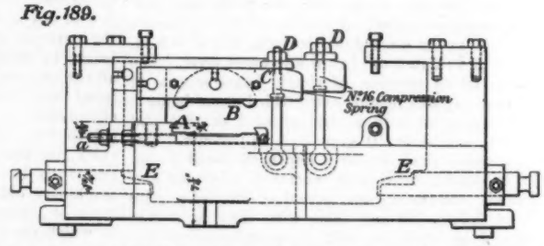
A.	6¼ in.	diameter	..	..	..	..	..	..	Roughing.
A.	6½ in.	diameter	..	..	..	..	..	..	Finishing.
B.	4¾ in.	diameter	..	..	..	..	..	..	Roughing.
B.	5 in.	diameter	..	..	..	..	..	..	Finishing.
C.	Form cutter		..	..	..	..	..	..	Finishing.

All high-speed steel, one spare cutter for each, making a total of ten cutters.

FIGS. 184 TO 190. JIG FIXTURE FOR ARM OF RADIAL DRILLING MACHINE.







who, when lecturing on his recent studies of this subject before the Chemical Society last February, made use of the following arrangement. By means of a Gaede pump he sucked pure rarefied nitrogen through two horizontal tubes in series, A containing the widely separated electrodes of an induction apparatus, and B, a wider tube, several metres in length. Through side tubes other gases were introduced into B, close to the end of A; these gases, it will be understood, mixed with the nitrogen after it had been exposed to the discharge, but were not themselves exposed to the electric stress. After turning on the discharge in A it was seen that a yellowish cloud of active nitrogen travelled along B; when the discharge was turned off, the luminescence disappeared, persisting at best a few minutes. When acetylene was introduced into B, a lilac tint was developed, the spectrum showed the well-known cyanogen band, and the presence of hydrocyanic acid could be demonstrated by the Prussian blue test. Similarly, the active N reacted with vapours of mercury with the formation of a nitride (yielding on decomposition in a test tube, ammonia); when a U-tube containing a globule of liquid mercury was inserted between A and B, the yellow gas "fouled" the mercury, i.e., when the mercury was shaken to break the skin on its surface, the liquid metal turned into a grey, pasty mass, which, on testing, again gave ammonia. Ordinary nitrogen would not have shown either reaction. By reacting with the mercury, the N lost its activity

When the experiment was made with mercury vapour, the mercury spectrum was observed; when with the liquid mercury, the mercury lines were absent. The spectrum of the active nitrogen itself was that of nitrogen, in which some lines were absent. When some oxygen, or also certain other compounds (to be mentioned later) were introduced into B, the yellow colour faded out; but examination through blue glass showed that a bluish light was produced by mixing the two gases, and this light had a spectrum characterised by peculiar bands, β and γ; the β bands, Professor Strutt explained, could not be produced in other ways, but the γ bands appeared when oxides of nitrogen were introduced into a Bunsen flame. On the other hand he had been quite unable to prove the presence of nitrogen oxides in his active nitrogen. The point is important in view of the oxidation of atmospheric nitrogen in the electric arc and Koenig and Elöd had suggested that the electric discharge passing through air produced a peculiar kind of oxygen (not ozone) which reacted with active nitrogen; but Professor Strutt has so far failed to confirm this observation. When he first described his experiments Tiede and Domcke had objected that his nitrogen, although purified by prolonged treatment with phosphorus, still contained traces of oxygen which were essential to the phenomena, whilst he himself had insisted on the purity of the nitrogen. Further experiments have convinced Professor Strutt, that neither side had been quite right; the active nitrogen, which Tiede questioned, is real—the reactions shown prove it—but a trace of some other substance seems to be essential. That need not be oxygen, however; carbon monoxide or dioxide, hydrogen sulphide and hydrocarbons like ethane and methane, apparently almost any substance, in fact, would do; 1/30,000th part of methane sufficed, for instance; a little oxygen favoured activation, above 2 per cent. destroyed it. In these experiments Strutt purified his nitrogen by heating it in contact with metallic sodium. It would then appear that activation, like catalysis, requires the presence of at least a trace of some other substance, and there the matter rests for the present.

Professor Strutt did not mention the possibility that the volatilised metal of the electrodes (aluminium) might be concerned in the phenomena, which seems not improbable. But he dwelt on the electrical conditions of the discharge. The circuit should contain Leiden jars; when a low-capacity discharge gap was placed in series to the A tube, so that the active nitrogen crossed the second gap, the activity of the nitrogen was destroyed. The phenomenon thus seemed to be reversible, as in the production of other endothermic substances. When oxygen is ozonised by heat, the temperature should be high, but the cooling must be rapid; if the ozone were subsequently passed through a second, less hot tube—corresponding to the second discharge gap—the ozone concentration would be lowered. In drawing attention to this analogy, Professor Strutt did not wish to commit himself to the view that his activation was necessarily due to high temperature. He also investigated which portion of the discharge is most active. For this purpose he used a discharge tube, the two electrodes of which are rigidly fixed to one another, but can together be pulled up and down the bulb; the gas current from a lateral tube is fed transversely across the bulb, and this transverse current of nitrogen can thus be made to cross any portion of the discharge. Now in the ordinary tube discharge there is the dark space quite close to the kathode, and then come the blue negative glow, the Faraday dark space, and finally the reddish positive column up to the anode. The blue glow proved the most active; the activation vanished almost in the second dark space, and was about half its previous maximum throughout the positive column. Thus the blue discharge, obtained by approaching the kathode or by inserting capacity, seems to be the most effective.

TEMPLETS, JIGS AND FIXTURES.—No. VI.

By JOSEPH HORNER.

THE illustrations in this article relate to fixtures and jigs designed and used by Messrs. James Archdale and Co., Limited, of the Manchester Works, Birmingham.

The arm of a radial drilling machine is shown by

Figs. 184 to 186, the jig fixture in which its pillar is bored in Figs. 187 to 189, and the boring bar with cutters in Fig. 190. The arm is located by the long facings A, A, on which the saddle is mounted and slides. These lie on the tooled faces A, seen in

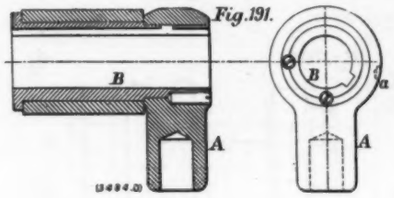


Fig. 189. The arm is pulled up against the square edge seen there, spot-faced, with the long hook bolts *a*, the nuts of which are tightened against the outside edges of the fixture. The arm is held down by two compensating levers B, B, Figs 188 and 189, the convex ends of which make contact with the curved outside portion of the arm as they pivot on their central pins, secured with grub screws. These levers are carried in two pivoted clamps C, C, held down by eyebolts D, D. The clamps are each formed of two flat bars held apart with distance pieces (see Fig. 188), and united by bolts and nuts to form one unit, while carrying the accommodating levers B, B, freely between them. The two clamps are of different lengths to suit the tapering form of the arm.

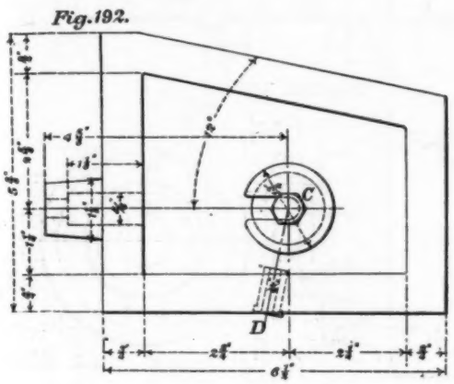
The pillar portion that stands at a right angle with the arm, and which is the part that has to be bored (see Figs. 184 to 186 takes up its position in the open space seen to the left of Fig. 188, within which it is steadied by the various set screws provided. It receives further support by the bevelled ends of the sliding pins E, E, shown in Fig. 189.

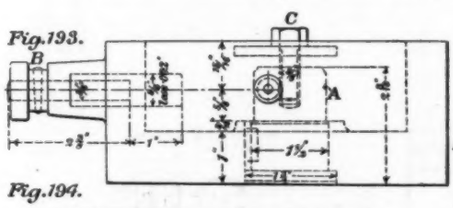
The boring bar, Fig. 190, is guided by the bushes F, F, seen in Figs. 187 and 188, in which the body of the bar, 4 in. diameter, Fig. 190, fits. It bores the two holes seen in Fig. 184, 5 in. at the top and 6½ in. at the bottom, and faces and rounds the lower end. Five cutters are used, and a spare cutter for each, all of high-speed steel. Cutter A roughs to 6½ in. and finishes to 6½ in. Cutters B rough to 4½ in. and finish to 5 in. Cutter C is a form cutter imparting the rounding edge.

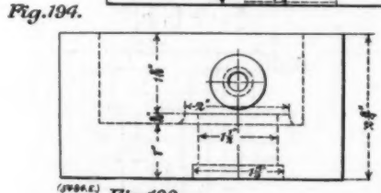
The group of illustrations, Figs. 191 to 200, show how it is sometimes necessary to minutely divide the operations, even in the production of simple interchangeable details. Fig. 191 shows the piece to be tooled, a starting lever boss for one of the radial drilling machines manufactured by Messrs. James Archdale and Co. The piece comprises an inner and an outer portion, the two being secured with two grub screws that occupy a precise relation to the angular position of the keyway, which latter is also related to the angle of the lever which fits the hole in the arm of the boss.

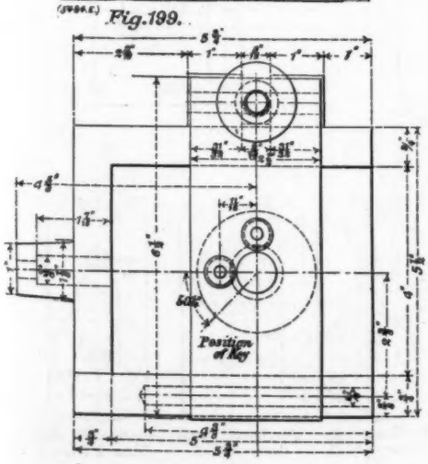
The parts having been previously turned, the outer boss A is put into the fixture, Figs. 192 to 194, for one purpose only, to have the shallow locating hole, *a* in Fig. 191, drilled. It fits by its bore, 1½ in. with 0·002 in. clearance, on a shouldered stud A, which is fitted and keyed in the bottom metal of the fixture. It is located by the spring pin B, Fig. 193, which enters into the lever hole in the arm of the boss, and is clamped down with the washer and screw C. The locating hole is then drilled through the bush D inserted in one side of the fixture at an angle of 12 deg. To bring this upright, the opposite side of the fixture is cut at an angle of 12 deg.

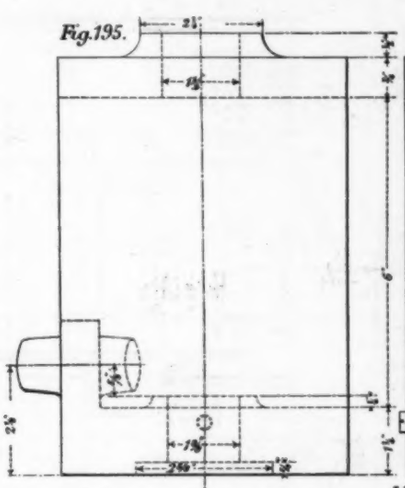
In the assembling jig, Figs. 195 to 197, the sole function is the insertion of the bush B, Fig. 191, in the outer body A. The latter is carried on the lower portion, 1½ in. diameter, of the spring stud A in the base, Fig. 196, being located with a spring plunger B, Fig. 197, which enters the shallow locating hole just now drilled. The bush is carried on a plunger C in the top portion, Fig. 196, provided

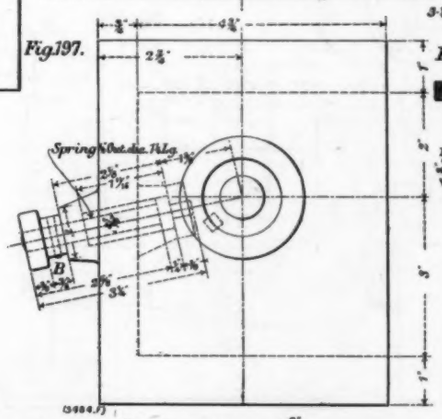


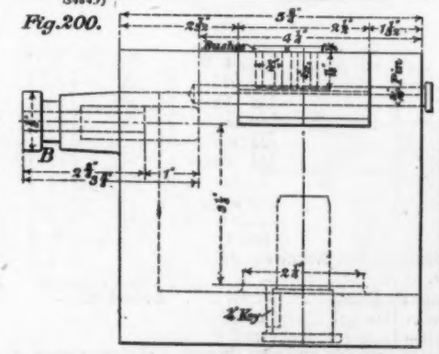


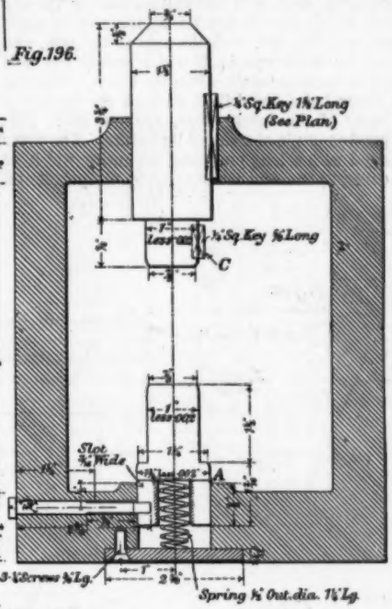


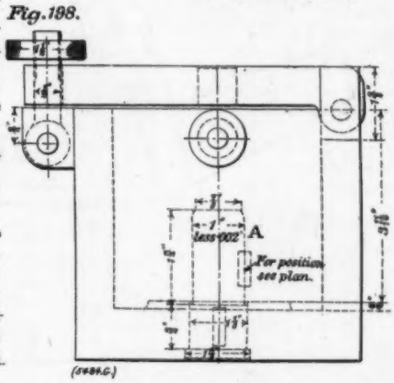












FIGS. 191 TO 200. JIG FOR BOSS OF STARTING LEVER.

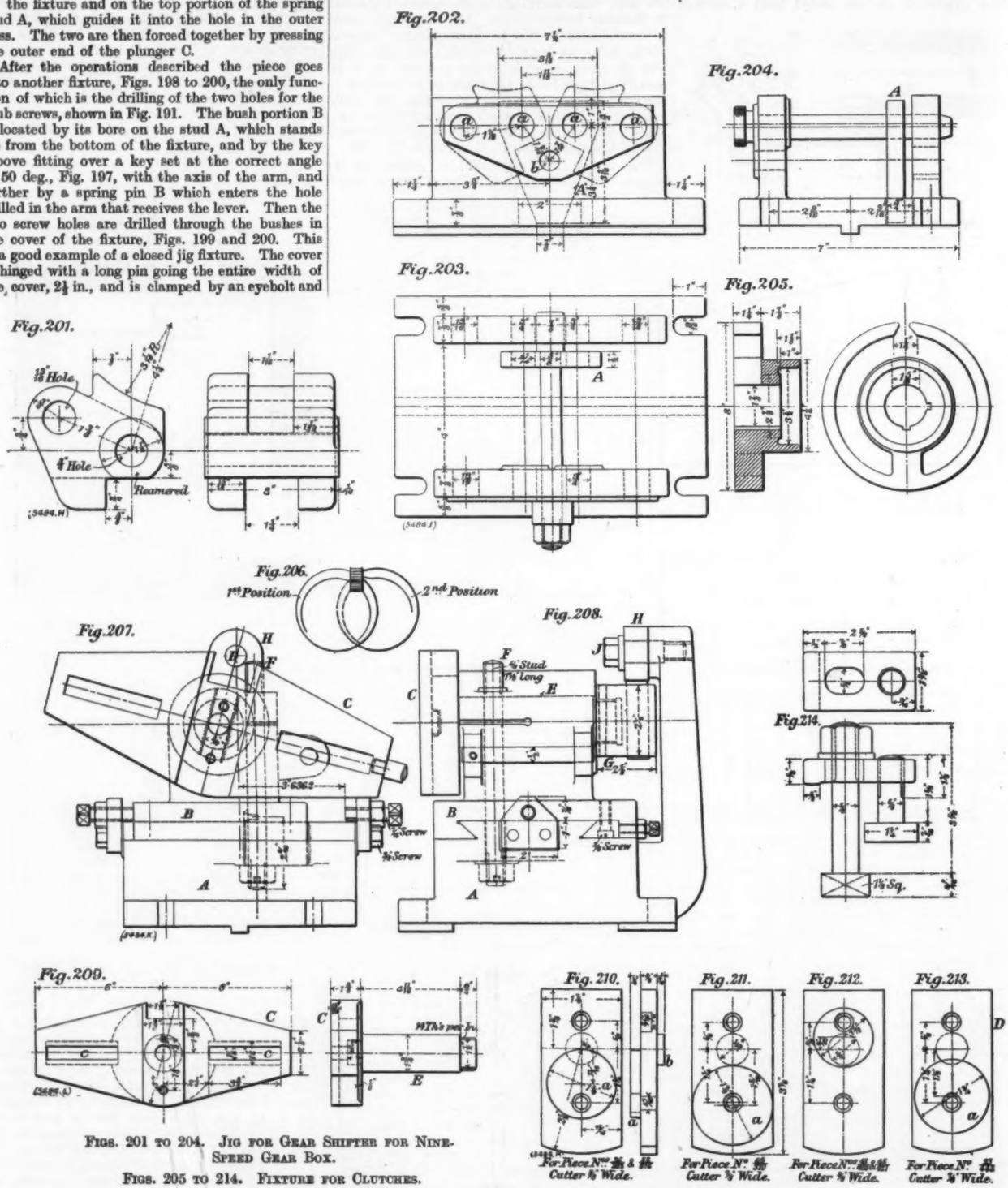
In the assembling jig, Figs. 195 to 197, the sole function is the insertion of the bush B, Fig. 191, in the outer body A. The latter is carried on the lower portion, 1½ in. diameter, of the spring stud A in the base, Fig. 196, being located with a spring plunger B, Fig. 197, which enters the shallow locating hole just now drilled. The bush is carried on a plunger C in the top portion, Fig. 196, provided

with a key to fit the keyway in the bush, Fig. 191, and is itself prevented from turning into a position incorrect with relation to the arm portion in the lower part of the jig by a key in a groove in the body of the fixture and on the top portion of the spring stud A, which guides it into the hole in the outer boss. The two are then forced together by pressing the outer end of the plunger C.

After the operations described the piece goes into another fixture, Figs. 198 to 200, the only function of which is the drilling of the two holes for the grub screws, shown in Fig. 191. The bush portion B is located by its bore on the stud A, which stands up from the bottom of the fixture, and by the key groove fitting over a key set at the correct angle of 50 deg., Fig. 197, with the axis of the arm, and further by a spring pin B which enters the hole drilled in the arm that receives the lever. Then the two screw holes are drilled through the bushes in the cover of the fixture, Figs. 199 and 200. This is a good example of a closed jig fixture. The cover is hinged with a long pin going the entire width of the cover, 2½ in., and is clamped by an eyebolt and circular nut. The pieces are thus rapidly inserted and removed.

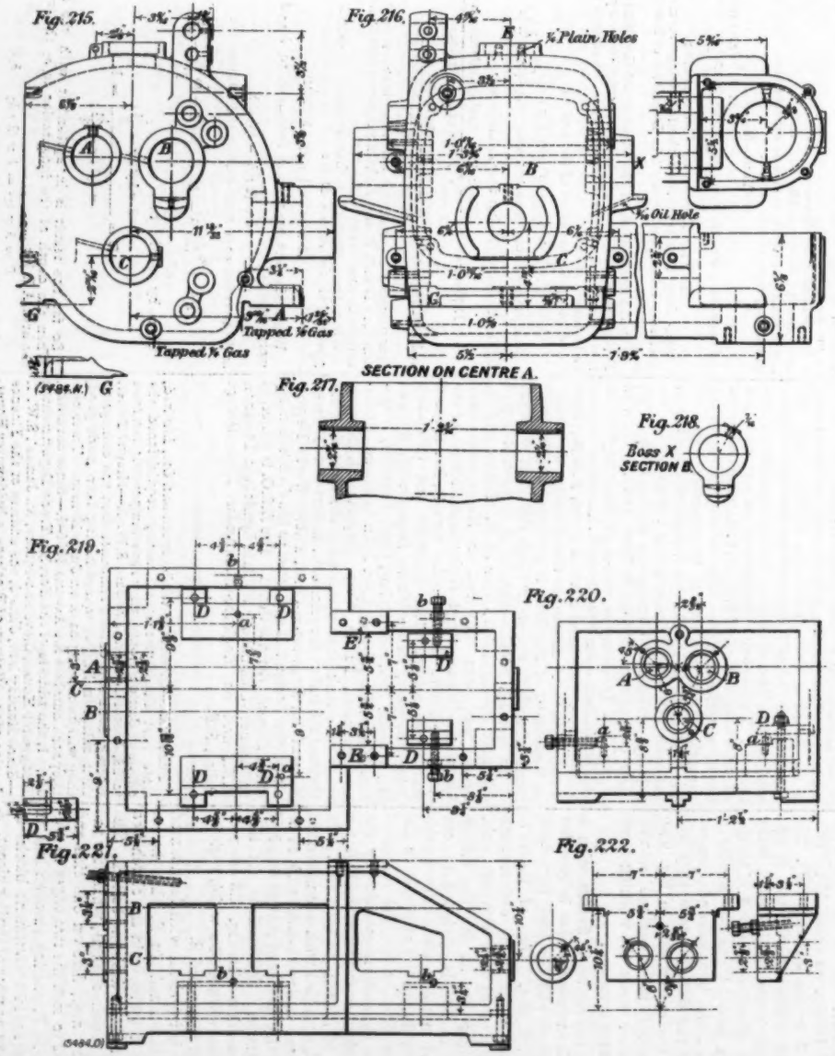
Fig. 201 illustrates a gear shifter for use in a nine-speed gear-box. It has been tooled elsewhere, leaving the gap, 1 1/16 in. wide, to be milled. This is done in the fixture, which holds two pieces at one time, Figs. 202 to 204. Each piece is located by two pins that are passed through the two pairs of holes *a*, *a*, *a*, *a*, Fig. 202, so disposed that the bottom of the gap to be milled becomes horizontal. Two of the pins—the outer ones—pass through the upright walls of the fixture, two others go through the uprights and also through a clamping plate A, while a bolt goes through the uprights and plate in the holes *b*. The work is inserted, the pins put in place and the clamping plate is tightened up against the work, gripping it against one upright with the central bolt in *b*. The clamping plate can be slid back, ¼ in., to allow the work to be put in. When tightened up, it bears against the face of a recess in the foot, in which it has lateral freedom of movement.

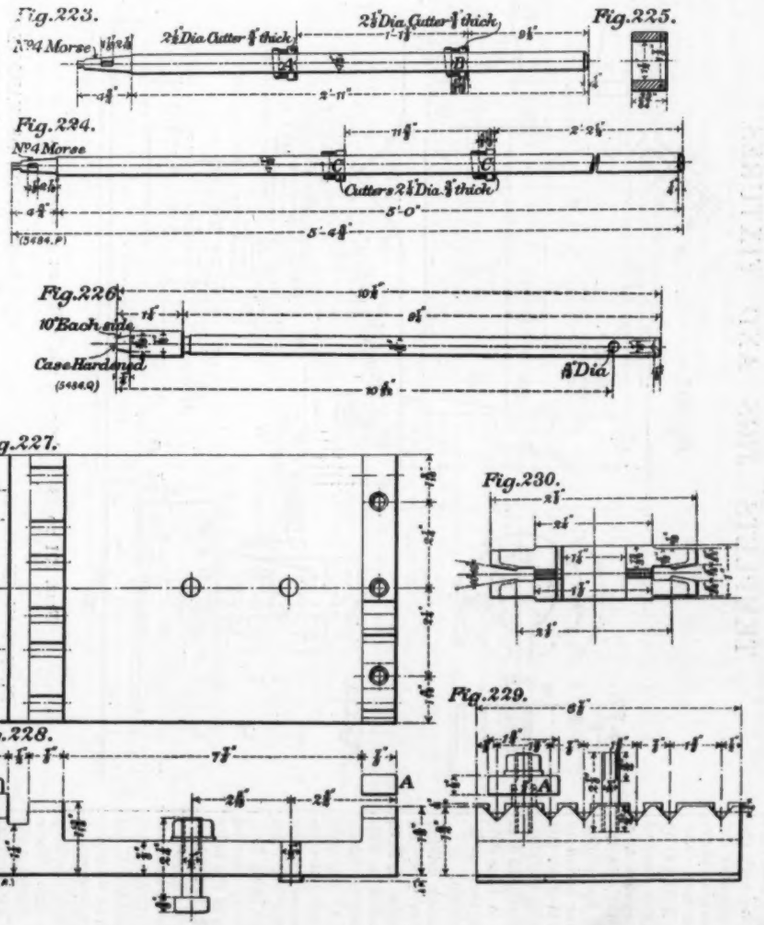
The next group of drawings, Figs. 205 to 214, illustrates a fixture which is built up of several pieces to perform a very simple function, that of holding and setting the clutch, Fig. 205 (used on radial drilling machines), while milling the bevelled edges that receive the wedge block by which the clutch is expanded circularly. The turning, boring and key-grooving have been already done, leaving only the rim to be cut through to the double bevel. Two settings are required for



FIGS. 201 TO 204. JIG FOR GEAR SHIFTER FOR NINE-SPEED GEAR BOX.

FIGS. 205 TO 214. FIXTURE FOR CLUTCHES.





FIGS. 215 TO 225. JIG FIXTURE FOR NINE-SPEED GEAR BOX.
FIGS. 226 TO 230. FIXTURE FOR SENSITIVE FEED LEVER.

this, as indicated by the sketch, Fig. 206, which shows the two positions of the clutch relatively to the milling cutter. The same fixture is made to serve for holding the clutches used in different machines by the insertion of suitable plug plates that fit in the portion of the fixture which is canted to the angle required.

The general assembly of the fixture is shown in Figs. 207 and 208, with which the more detailed views in the other drawings should be compared. A base A, fits with tongues to the grooves in the table of the milling machine. It is provided with vees by which adjustment is made of the sliding bracket B, Figs. 207 and 208, that receives the work-holder C, Fig. 209, seen in its place in the drawing, Figs. 207 and 208. A slot in this, 1⅞ in. wide, Fig. 209, receives either of the plug plates seen in Figs. 210 to 213, these being drawn to an enlarged scale. The clutch is located to its plug plate by the boss *a* on the plate, which enters the bore of the clutch, 1⅞ in., or 1⅝ in., or 1⅜ in. A stud *b* on the opposite face of the plug plate enters a ¾-in. hole in the portion of the fixture C, Figs. 207 to 209, through which the angle is imparted to the edge to be milled. These plates so locate the clutch to be milled that the slot is opposite to the axis D of the fixture, Fig. 207. The plates are secured with cheese-head screws which enter them and go into tapped holes in the fixture—compare Fig. 209 with Figs. 210 to 213.

The portion C of the fixture which carries the plug plates is itself carried on the end of a cylindrical body E, Figs. 208 and 209, that passes through the boss of the slide B, the boss having a split lug at one end, and a clamping bolt F. At the opposite end the boss is screwed to receive a tail-piece G, Fig. 208, which is drilled and tapped through for a ¾-in. pin H, having an eye, Figs. 207 and 208. This

swivels on a stud J which is tapped into a boss that terminates a bracket or arm cast in one with the base A of the fixture. This fixture determines the angle of the setting of the carrier of the plug plate, one position of which is seen in the face view, Fig. 207. The work is clamped in the holder C by the clamps shown in Fig. 214. The square head of the longer bolt slides in the 1¼ in. spaces *c*, *c*, Fig. 209, and the shank of the bolt slides in the ⅝-in. space, and the clamping is done by turning the shorter bolt, which imparts a lever action to the clamping plate. The screws seen in Figs. 207 and 208 are used for adjusting and setting the slide B so that the work-holder will swivel exactly 15 deg. each way—one position being shown in Fig. 207, which by reference to Fig. 205 will be seen to be half the included angle of the wedge section.

The nine-speed gear-box for a radial drilling machine, illustrated in Figs. 215 to 218, on page 631, has its three main shaft holes A, B, C, bored in a jig fixture, shown by Figs. 219 to 221. The feet A, A, of the box are the portions by which it is located on facings by two pegs at *a*, *a*,—compare Fig. 220 with the plan view, Fig. 219—in conjunction with three steadying set screws at *b* in the same figures. It is held securely with six clips and bolts at D in Fig. 220, their centres being indicated at D in Fig. 219. The boring bars are steadied at the right hand end of the jig for two of the holes A and B, with bushes in a bracket, Fig. 222, which is bolted through its flanges to facings E, E, on the fixture, Fig. 219, the bracket coming down within it to bring the holes into line with those in the solid wall at the left hand of the fixture. The third hole C has its second bush in the fixture wall, seen at the right.

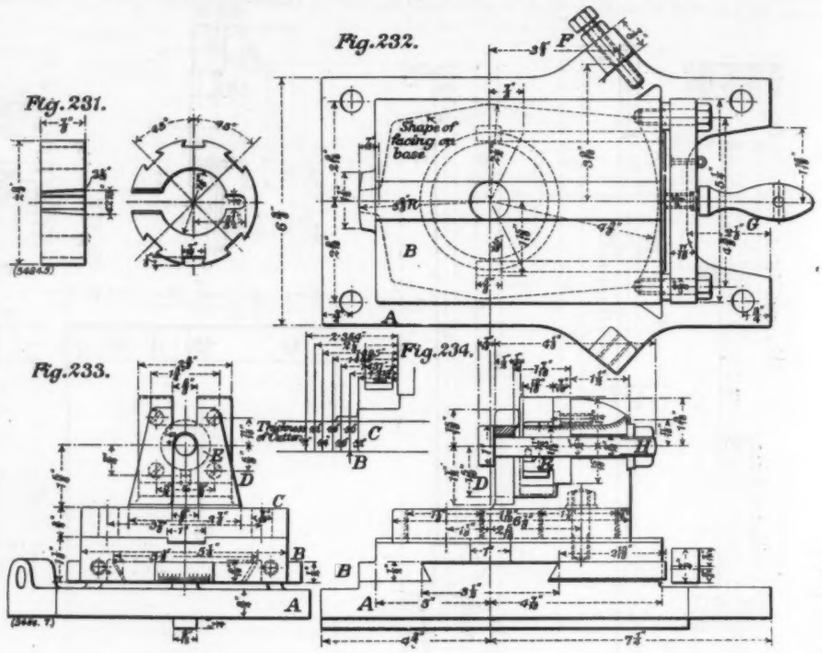
The boring bars are shown by Figs. 223 and 224, and the loose bushes, through which the body of the bar passes, are illustrated in Fig. 225. These can be removed with the bar to avoid changing the cutters. Two sets of cutters are used for roughing and two for finishing. Slip bushes—not shown—are inserted between those which are permanent and the boring bars.

A plunger for a sensitive feed lever, illustrated in Fig. 226, on page 631, has to be milled at one end to an angle of 10 deg. on each side. This operation is performed in the fixture, Figs. 227 to 229, in which six levers are treated at one time. At one end the levers lie in vees, being clamped two and two with the plates A. At the other end they lie in parallel recesses having a clearance of 0·002 in. The bevelled ends project at the right hand of the fixture where they are milled by means of the cutter seen in Fig. 230, this cutter being carried in a vertical spindle machine. As the cutter wears the working faces are packed outwards with a washer.

The next example represents a fixture with a large amount of detail included, which is intended to deal with a range of clutches that vary both in width and angle of slot. One of these is shown in Fig. 231 annexed. It is cut through on one side at an angle of 2½ deg. with the axis. There are other toolings on it, but the fixture shown by Figs. 232 to 234 is designed to cut the bevelled slot and nothing else. The justification for the elaborate design lies of course in the large numbers that are dealt with. The fixture is bolted to the table of the milling machine by the base A, on which a circular swivel slide B has a swivelling movement of 10 deg. on each side. On this is another slide C, provided with a longitudinal adjustment which allows the work-holder D to be set to suit the various thicknesses of cutters required for the different clutches. Graduations for this purpose shown in connection with Fig. 233 are provided on the side of the work-holder which register with the zero mark on the swivel B.

The clutch which is being dealt with is mounted by its bore on a case-hardened pin E, that has a ¼-in. key to fit in the key groove in the clutch (see Fig. 231), being then tightened by the bolt H. The swivel B is set to the required angle, which for the clutch illustrated is 2½ deg., first on one side and then on the other so as to mill the two edges in succession. Two screws F, F, passing through lugs in the base are brought against abutment blocks to locate the angles for any number of similar pieces. A locking handle G is used for swinging the swivel plate.

TEMPLETS, JIGS AND FIXTURES.



FIGS. 231 TO 234. FIXTURE FOR A RANGE OF CLUTCHES.

BIRTHDAY HONOURS.

THE first instalment of honours granted on the King's birthday was published last Monday. It includes the names of a number of engineers and men connected with engineering enterprises. Among the new Baronets are Mr. Guy Calthrop, General Manager of the London and North-Western Railway, who is the Controller of Coal Mines and the head of the Department of the Board of Trade which has control of the coal mines of the United Kingdom; Mr. Robert McAlpine, head of the firm of Messrs. McAlpine and Sons, contractors. The honour of knighthood has been conferred on Mr. Frank Baines, C.B.E., M.V.O., principal architect to the Office of Works, who was responsible for the strengthening of the roof of Westminster Hall; on Mr. Thomas Octavius Callender, managing director of Callender's Cable and Construction Company. In the Military Division of Companions of the Bath is the name of Engineer-Captain William Toop, R.N., and in the Civil Division the names of Engineer-Captain Charles William John Bearblock, R.N., and of Captain (Commodore, 2nd Class) Herbert Lyon, R.N.R. (Vice-Admiral retired). Also in the Civil Division the dignity of Companion of the Bath is conferred on Mr. Basil Mott, M.Inst.C.E., and on Sir Hugh Bell, past president of the Iron and Steel Institute. A Companionship of the Most Distinguished Order of St. Michael and St. George has been conferred on Major (temporary Lieutenant-Colonel) Ralph Kirby Bagnall-Wild, of the Royal Air Force. In the Indian Service, Mr. Bernard Martin Samuelson, Chief Engineer and Officiating Joint Secretary, Public Works Department, Burma; Mr. William Frederick Holms, Chief Engineer, Irrigation Works, Punjab; and Mr. John Desmond, Executive Engineer, Public Works Department, Nagpur, receive the rank of Companions of the Most Eminent Order of the Indian Empire. Mr. Robert West Holmes, M.Inst.C.E., Engineer-in-Chief, Public Works Department, New Zealand, is appointed to the Companionship of the Imperial Service Order. The D.S.O. is conferred on Engineer-Commander William Symington Torrance, R.N., and on Engineer-Commander Elias George Pallot, R.N.

PERSONAL.—Messrs. J. W. Jackman and Co., Limited, state that the Government having requisitioned the offices at Caxton House, they have temporarily removed to 28, Victoria-street, London, S.W. 1.—Messrs. Fuller, Horsey, Sons and Cassell announce that the damage to their offices in Billiter-square having been made good, they will be moving back on June 15 next. Their new telephone numbers are Avenue 3008–9.—Since Saturday, June 1, the address of the Foreign Trade Department is Bridgwater House, Cleveland-square, St. James', S.W. 1.—Since Monday last, June 3, the address of the Finance Section of the Ministry of Blockade is Bridgwater House, Cleveland-square, St. James', S.W. 1.

THE DEFINITION OF HARDNESS.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with keen interest Dr. W. Cawthorne Unwin's helpful article on Martel and Brinell's Hardness tests in your issue of May 17, and I would like to ask whether the deflection of the ball does not materially modify the theoretical conclusions. Referring to the diagram on page 535, the deflection of the ball appears to me to cause a diminution to the depth *h*, and there is the tendency to throw up a crater edge at C and D, and, finally, does not the ball deflection tend to make the distance between C and D greater than that due to the true sphere?

Yours faithfully,
A. E. PARNACOTT.

Penge-lane, Penge, S.E., May 22, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—May I be permitted the following comment on Professor Unwin's note on "The Definition of Hardness" in your issue of May 17.

The demonstration of the identity of the Martel and Brinell hardness numbers is valid only if an approximation is made which a more exact treatment shows to be inadmissible.

Adopting the notation of the article,

$$\text{Area of spherical calotte} = 2\pi r h_1.$$

$$\text{Volume of spherical calotte} = \pi h_1^2 \left(r - \frac{h_1}{3}\right).$$

By definition of the hardness numbers,

$$\text{D (Martel)} = \frac{\text{Work done during indentation}}{\text{Volume of indentation}}$$

and

$$\text{H (Brinell)} = \frac{\text{Applied load}}{\text{Area of spherical calotte}}$$

It is proposed to establish a relation between each of the numbers D and H and *k* the fluid stress of the material under the conditions of the test.

When the indentation has reached a depth *h* the pressure on the area C D is:

$$k\pi a^2 = k\pi(2rh - h^2).$$

When the indentation is increased to $h + dh$ the work done is:

$$k\pi(2rh - h^2)\,dh,$$

and the total work done during indentation is:

$$k\pi \int_0^{h_1} (2rh - h^2)\,dh = k\pi h^2 \left(r - \frac{h_1}{3}\right)$$

Then, by definition,

$$D = \frac{k\pi h_1^2 \left(r - \frac{h_1}{3}\right)}{\pi h_1^2 \left(r - \frac{h_1}{3}\right)} = k$$

So far the result is in agreement with the article. When the depth of the indentation is h_1 the load on the area A B is:

$$P = k\pi a_1^2 = k\pi(2rh_1 - h_1^2)$$

and, by definition,

$$H = \frac{k\pi(2rh_1 - h_1^2)}{2\pi r h_1} = k\left(1 - \frac{h_1}{2r}\right)$$

Hence H and D differ by the quantity $\frac{k h_1}{2r}$, and they can only be regarded as identical if, as in the article, the circular area $\pi(2rh_1 - h_1^2)$ is assumed sensibly equal to that of the spherical calotte $2\pi r h_1$.

Consider the magnitude of this difference in cases representative of the practical limits of the Brinell test with a load of 3,000 kg. applied through a ball of diameter 10 mm. :—

a_1	h_1	$k = \frac{P}{\pi a_1^2}$	D	H	$\frac{D}{H}$
1.00	0.101	956	956	946	1.01
3.00	1.00	106.2	106.2	95	1.12

The difference between D and H is due entirely to the difference in area of the circle and the spherical calotte, and in the above cases is 1 per cent. and 12 per cent. If, however, the Brinell hardness number were defined :

$$\frac{\text{Applied load}}{\text{Circular area of indentation}}$$

the identity with the Martel number would be complete, and if the results of Martel's experiments are so conclusive as to outweigh the considerations which governed Brinel in dividing the load by the spherical area, a case appears to be made out for the adoption of this definition.

Yours faithfully,

F. BUCKINGHAM.

The Victoria University of Manchester, May 28, 1918.

"DUMPING."

TO THE EDITOR OF ENGINEERING.

SIR,—The very interesting leader in yesterday's issue of your journal will be received with mixed feelings; but there is one question on which discussion might prove profitable, if only it be treated dispassionately, viz. : How comes it that "Every progressive country except Britain already to some extent protects its market and industries from dumping" ?

You, Sir, allude to what has been done in Canada, where they have an enormous surplus of wheat, and where the manufacture of agricultural implements can be fostered at the expense of the wheat growers ; and in most countries in the world we find a surplus of some or other natural product available for "protection" ; but England is not so fortunate !

Who is to pay for protecting our industries ?

Your obedient Servant,

June 1, 1918. "ONE WHO DOESN'T KNOW."

THE STABILITY OF AEROPLANES.

TO THE EDITOR OF ENGINEERING.

SIR,—We do not propose to accept Mr. Webb's invitation to enter into a philosophic discussion of the relative merits of sound and unsound treatments of dynamical problems in educational work, nor are the elementary laws of dynamics, as far as we understand them, affected by the question whether plane sections remain plane in a stressed beam. Our object in writing was merely to warn students against accepting a superficially simple treatment of a profound dynamical truth.

Every schoolboy is aware that the external force acting upon a body is measured by the product of the mass into the acceleration of the body in the direction of that force. Mr. Webb has, however, no hesitation in violating this conception in equation (1) in his article. It is obvious that the total rates of change of momentum along O Y and O Z are $m\,d\,v/d\,t$ and $m\,d\,w/d\,t$ irrespective of any angular rotations the body may possess. If Mr. Webb is using *axes fixed in space*, as he professes to do, his fundamental equations are thus wrong. Had he referred u, v and w to rotating axes, additional terms would, of course, arise.

We quite admit the contention that no trouble arises over the resolution of the moments of inertia of the aeroplane when the principle axes of the body are parallel to his fixed axes of reference, provided it be realised at the same time that Mr. Webb's treatment is thus restricted to a very special case, viz., where the machine is flying at that angle of attack which makes the principle axes coincide with, say, N, W and vertically upwards. In §5 he conveys the impression that only in banked or spiral flight does this trouble arise, but it is evident that the difficulty exists for any flight other than that at the particular angle referred to.

Mr. Webb is fortunately not the first to attempt the problem from the obvious method of fixed axes, and it is clear that if the theory of stability could be lucidly compressed into two columns of ENGINEERING there would be no need for the elaborate treatments that have been forthcoming. The correct forms of the equations of motion with reference to fixed axes are as follows, from which the criterion of stability will be found to be the same as for moving axes :—

Longitudinals :—

$$m\frac{d\,u'}{d\,t} = m\left\{\theta\,(g\cos\Theta + U\,X_u) + u'\,X_u + w'\,X_w + q\,X_q\right\}$$

$$m\frac{d\,w'}{d\,t} = m\left\{\theta\,(g\sin\Theta + U\,Z_w) + u'\,Z_u + w'\,Z_w + q\,Z_q\right\}$$

$$m\,K^2_D\frac{d^2\theta}{d\,t^2} = m\left\{\theta\,U\,M_w + u'\,M_u + w'\,M_w + q\,M_q\right\}$$

Laterals :—

$$m\frac{d\,v'}{d\,t} = m\left\{-\phi\,g\cos\Theta - \psi\,(g\sin\Theta + U\,Y_v) + v'\,Y_v + p\,Y_p + r\,Y_r\right\}$$

$$m\left\{k^2_A\frac{d^2\phi}{d\,t^2} - K^2_E\frac{d^2\psi}{d\,t^2}\right\} = m\left\{-\psi\,U\,L_v + v'\,L_v + p\,L_p + r\,L_r\right\}$$

$$m\left\{k^2_C\frac{d^2\psi}{d\,t^2} - k^2_E\frac{d^2\phi}{d\,t^2}\right\} = m\left\{-\psi\,U\,N_v + v'\,N_v + p\,N_p + r\,N_r\right\}$$

Θ is the angle of climb.

u', v' and w' are velocities referred to axes fixed in space, along and perpendicular to the flight path.

$m\,k^2_E$ the product of inertia about the axis $o\,y$.

θ, ϕ and ψ have the same significance as in Mr. Webb's article.

It requires no deep physical or mathematical intuition to realise that the expressions for the motion referred to moving axis must be different from those for fixed axes. In conclusion, we should like to state that a simple proof of a difficult theorem based on simplified assumptions is always acceptable for the less mathematical student, but under no circumstances should a so-called general proof, limited to a special case, and violating elementary dynamical laws, be allowed to pass unchallenged.

Yours faithfully,

W. L. COWLEY.
H. LEVY.

The National Physical Laboratory, Teddington, Middlesex, May 28, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to the article by Mr. Webb on this subject in your issue of May 3, and Messrs. Cowley and Levy's criticism and Mr. Webb's reply to their criticism, I would say that I was surprised to find in your issue of May 31 that the subject was apparently dropped at such a point as would, in my opinion, lead intending students to think that they might well spend time in trying to master Mr. Webb's methods.

The following outlines what I think on the question :—

Mr. Webb says :

"Take axes 'fixed' in space $O\,x$, $O\,y$, $O\,z$" (and he takes his normal flight path parallel to $O\,x$).

"Let the velocities of the centre of gravity of the aeroplane be $U + u$, v and w parallel to $O\,x$, $O\,y$ and $O\,z$.

"Then total rate of change of momentum is :

"$m\frac{d\,u}{d\,t}$ parallel to $O\,x$

"$m\left(\frac{d\,v}{d\,t} - U\,v\right)$ parallel to $O\,y$

"$m\left(\frac{d\,w}{d\,t} + U\,q\right)$ parallel to $O\,z$."

These statements are obviously wrong, as with "fixed" axes they should be $m\frac{d\,u}{d\,t}$, $m\frac{d\,v}{d\,t}$ and $m\frac{d\,w}{d\,t}$ respectively.

Again, he makes another slip (which is generally necessary in order to bring a thing right again) by taking his air forces as :

$m\,(u\,X_u + w\,X_w + q\,X_q)$ parallel to $O\,x$
$m\,(v\,Y_v + p\,Y_p + r\,Y_r)$ parallel to $O\,y$
$m\,(u\,Z_u + w\,Z_w + q\,Z_q)$ parallel to $O\,z$.

According to this the air forces on the plane are independent of the "attitude" of the plane to the "fixed" axes, which is, of course, wrong (by "attitude" I mean "mutual inclinations between the axes of the plane and the fixed axes of reference $O\,x$, $O\,y$, $O\,z$).

The above expressions represent the "extra" air forces due to the velocities u, v and w on condition that the attitude remain normal, and are infinitesimal in magnitude when u, v and w are infinitesimal. Now an infinitesimal difference of attitude of the aeroplane from the normal coupled with the finite velocity U may sometimes be of far greater importance in affecting the extra air forces than the expressions mentioned by Mr. Webb and written above.

Yours faithfully,

WALTER C. M. PETTINGILL.

Rochester, June 2, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—The article published in your issue for May 3 on "Stability of Aeroplanes," by Mr. H. A. Webb, is to my mind the most important publication on the subject of aeroplane stability since 1914.

The object of the author, viz., to enable an engineer with ordinary mechanical knowledge of Newton's equations to grasp the meaning of the terms in the stability equations obtained by Bairstow at great elaboration is a very praiseworthy one.

In a very few institutions there are a small number of men gathered together who are able to work moving axes without, so to speak, jambing their fingers in this elaborate mathematical machine, the object of which is to save the labour required for clear thinking.

But unless one is constantly operating this machine one soon forgets the rules of the method and practically no engineer engaged directly in industry has time to keep his knowledge of moving axes in working order (except if it be his hobby)—even if he ever had such knowledge.

It is therefore such articles as that of Mr. H. A. Webb which really give knowledge to the world at large.

Yours faithfully,

WALTER H. BARLING.

"Cabar," Petersham-avenue, Byfleet, Surrey, June 1, 1918.

INDUSTRIAL COMBINATION

TO THE EDITOR OF ENGINEERING.

SIR,—Industrial combination, which is occupying the minds of manufacturers so much at the present time, is by no means a new doctrine as so many superficial thinkers seem to imagine. The principle is as old as the hills and the spirit of all past economic history calls loudly to manufacturers to combine and specialise more in their undertakings, in order to increase the world's productivity.

The only difference in the present movement in industry is that the greatest war the world has ever seen has forced on us the necessity to accelerate the progress of industrial combination to a speed hitherto unattained. The old belief in the supreme value of competition being the greatest incentive to cheap manufacture may have been right in days gone by when international competition was not so strong, but whilst admitting the value of healthy competition, we must not become obsessed with the notion and look upon it as a fetish for our belief, otherwise our efforts remain too parochial in character, and we lose that wide vision so necessary for the future of British trade.

There is such a thing as unhealthy competition, and when we view the sorry spectacle of a score or more firms, each making among other things a certain article, and each competing one with another for a portion of a total yearly trade the product of which may not be more than a few thousand pounds in value, how is it possible to argue that it has the tendency to cheapen manufacture. Its effect is just the reverse.

If we are again to attain the proud position our industry once occupied, we have got to adopt any and every means that will stimulate our factories to their greatest productive capacity. Syndication, or co-ordination of effort between firms in the same trade, will prove to be the greatest of all influences that will bring about the desired end. The operations of individual firms in each industry should be so arranged that the whole combine would act as one body. This would secure the interests of individual manufacturers and allow them to devote all their energies and all their initiative to that one great necessity—production, instead of having to spend half their time in fighting local competition and for ever struggling among themselves for a scrappy share of the existing trade in almost every line produced.

One is reminded of the old phrase : "A house divided against itself cannot stand," and surely this is the position of a great many trades in Great Britain to-day, and most certainly they will never withstand the terrific "offensive" we are to expect from international competition in the future, if we do not combine to present a bold and united front to other nations when struggling again for trade supremacy of the world.

Yours faithfully,

HOWARD F. SMITH.

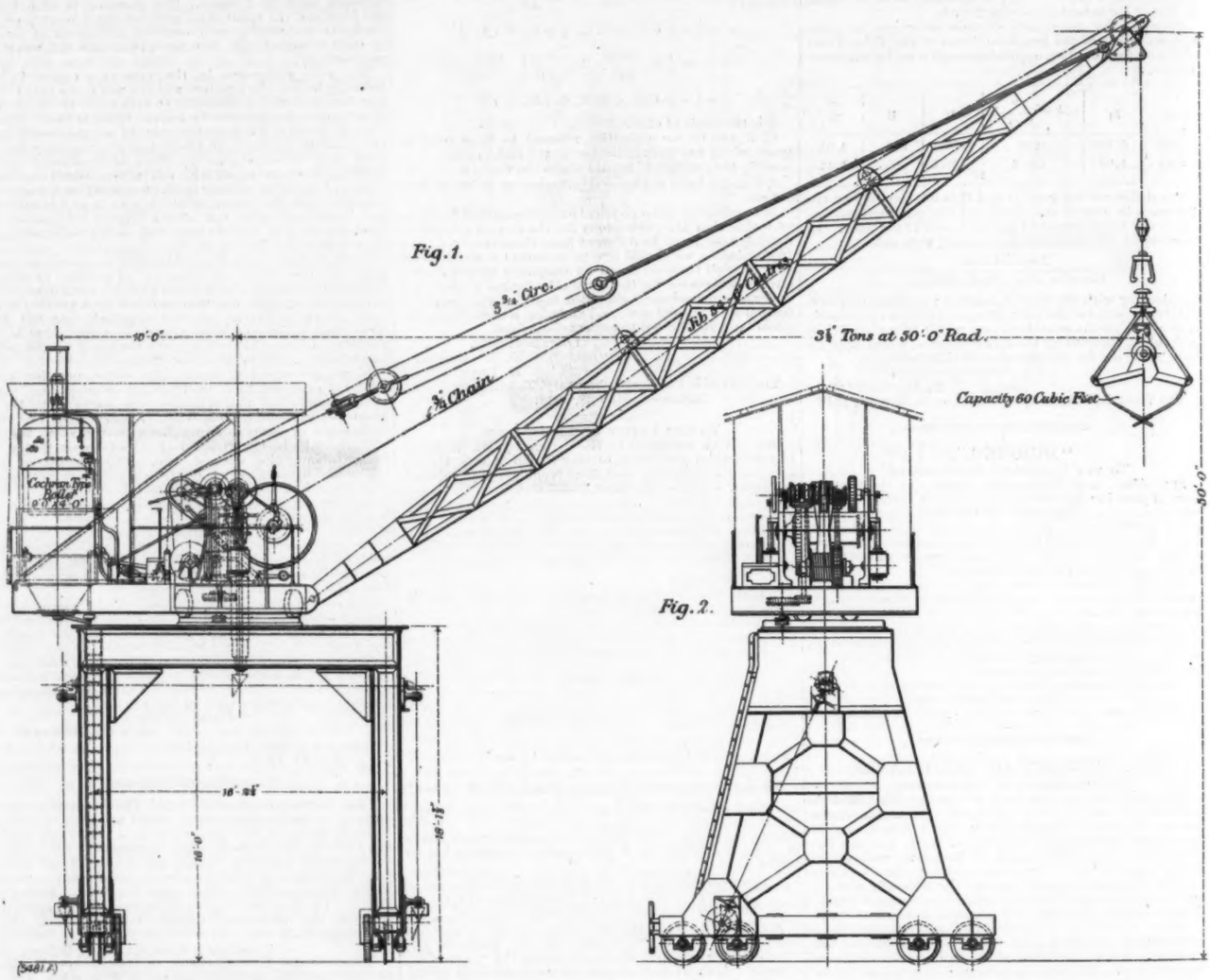
Hampton-street, Birmingham, May 31, 1918.

THE BRITISH SCIENCE GUILD.—The twelfth annual meeting of the British Science Guild will be held at the Mansion House on June 19 next, at 4 p.m., the Right Hon. the Lord Mayor presiding. An address on "Education, Science and Leadership," will be given by the Right Hon. Lord Sydenham, G.C.S.I., &c., and other speakers will be Sir Algernon Firth, Bart., and Sir Henry Newbolt, D.Litt. Cards of invitation may be obtained on application to the Secretary, British Science Guild, 199, Piccadilly, W. 1.

UNSATURATED HYDROCARBON IN GASOLINE.—Of the various cracking porcesses known in September, 1917, only one had attained considerable commercial development, we see from Technical Paper 181, drawn up by E. W. Dean and H. H. Hill, of the United States Bureau of Mines. This single process, however, which is owned and controlled by an oil company, produced 3,000,000 barrels of gasoline out of a total of 41,000,000 barrels marketed during the year 1915. Cracked petroleum always contain olefins and unsaturated hydrocarbons. These constituents used to be considered undesirable in motor fuels and they lowered their value. At present it is known that satisfactory motor fuels may contain 12 per cent and more of unsaturated constituents, and it is indeed claimed, not without reason, apparently, that their presence is advantageous in certain respects. In any case, however, the percentage of unsaturated hydrocarbons in an oil should accurately be known. The paper mentioned reviews the analytical methods available for this determination and proposes certain improvements in the application of these means. The unsaturated hydrocarbon can be absorbed by sulphuric acid ; this method is found rapid, reliable and fairly accurate, and is generally recommended. The second method, iodine-absorption, is stated to be accurate and moderately rapid, but it requires much care and some skill in the technique of iodometry. It is noteworthy that Dean and Hill do not recommend the methods of Hübl and of Wijs, which are alone described in most books on these tests, but the method which J. Hanus proposed in 1901 in the *Zeitschrift für die Untersuchung der Nahrungsmittel* ; Hanus uses iodine monobromide instead of the monochloride of the other chemists. The iodine numbers thus determined are, according to Dean and Hill, in fairly constant ratios to the numbers which the sulphuric acid absorption yields. The bromine absorption method proved less suitable than the iodine method. Finally, the Maumené acid-heat test was tried, which depends upon the degree of heat generated when the oil reacts with concentrated sulphuric acid ; this Maumené test was found unsuitable for highly unsaturated mixtures which may become so hot that some gasoline is volatilised.

3½-TON LOCOMOTIVE STEAM CRANE.

CONSTRUCTED BY MESSRS. JOHN H. WILSON AND CO., LIMITED, ENGINEERS, LIVERPOOL.



On the present page and page 638 we give illustrations of a locomotive steam crane recently constructed by Messrs. J. H. Wilson and Co., Limited, of Dock-road, Birkenhead. As shown in Fig. 1, annexed, the crane is intended to lift 3½ tons at a maximum radius of 50 ft. By means of worm-actuated gear the jib is adjustable between this extreme limit and a minimum radius of 35 ft. The crane is mounted on a travelling gantry built up of steel plates and channels, and, as shown in Fig. 2, each side frame of the gantry is very thoroughly stiffened and braced. The gantry is mounted on eight wheels, which are 2 ft. in diameter over treads and have cast-iron centres and Bessemer steel tyres. The axles are of Siemens-Martin steel, 4 in. in diameter at the centre and with 3½-in. journals 5½ in. long. The axle-boxes have adjustable gun-metal bearings. The drive to the travelling wheels is transmitted through bevel gearing, as best seen in Fig. 3, page 638. The crane has been proportioned so that the maximum load on any wheel can never exceed 8½ tons. The clear headway under the gantry is 16 ft. The pivot post round which the crane turns is of hammered iron, 10 in. in diameter. The jib, which is 54 ft. 6 in. long between centres, is of steel, and spreads out at its lower end to the full width of the bottom main casting of the crane bed.

The lifting gear is of the single-purchase type. The barrel is 18 in. in diameter and accommodates enough chain for a lift of 70 ft. The chain is of ¾-in. metal and is provided with a ball-bearing hook at its outer end. The jib-adjusting gear is operated by a steel wire rope of 1¼ in. diameter.

With full load the speed of lift is 200 ft. per minute. All adjustments of the crane are effected by power. The speed of travelling is 80 ft. per minute, whilst revolving can be effected at the rate of two complete turns in one minute.

The engines have two cylinders, 8 in. in diameter by 12 in. stroke, lagged with sheet steel, and are fitted with link-motion reversing gear. Claw clutches are used for operating the jib-adjusting gear and the travelling gear, whilst double-cone friction clutches are used for coupling up the engine with the revolving gear. The direction of revolution can thus be changed without reversing the engines. The gearing, pinions, roller paths, rollers, and all the travelling gear are of cast steel. The boiler is of the multitubular type, with 120 sq. ft. of heating surface and a grate area of 9 sq. ft. The shell is 4 ft. in diameter by 9 ft. high, and the working pressure is 100 lb. per square inch. There are 60 tubes 2 in. in diameter. The boiler is lagged with non-conducting material covered with sheet steel. The water tank, which holds 250 gallons is mounted under the tail end of the crane and serves as counterweight.

The general character of the crane is perhaps best shown in Fig. 3, page 638. The grab bucket there visible has a capacity of 60 cub. ft.. The total weight in working order is 52½ tons, the heaviest component piece weighing 5 tons, and the total cubic measurement for shipment is 1,850 cub. ft.

WERKSPOOR MARINE DIESEL ENGINES.

THE Nederlandsche Fabriek van Werktuigen en Spoorwegmaterieel genaamd "Werkspoor," of Amsterdam, generally known as Werkspoor, was the first firm to equip a sea-going vessel—the Vulcanus—with a Diesel engine, and it has since turned out quite a large number of motors. Several months ago its list of Diesel-engined vessels included 26 names, and on these there were 37 motors of an aggregate power of 33,000 i.h.p. At the same date there was in hand the machinery for seven boats—11 motors in all—with an aggregate of 17,000 i.h.p. This represents quite a comprehensive experience, but its value is much increased by the fact that Diesel-engined ships do not usually make Amsterdam a port of call. They are put upon routes where oil is plentiful and comparatively cheap, and hence the builders can do nothing to nurse the engines. They send them away in charge of engineers who have little experience of such machinery, and who are apt to be replaced by others who know still less about it. The result is that every weak spot is discovered by the very effectual method of being tested to destruction. Such an experience is very disconcerting to a designer, but it has the advantage that it leads to very rapid improvement. Each feature that fails or gives rise to complaint is subject to thorough investigation, with the result that satisfactory arrangements are soon attained. With highly skilled engineers and frequent returns to the makers' yard motors would suffer fewer breakdowns, but the process of evolution would be slower, and possibly less thorough. Certainly it would not be so distinctly in the direction of simplicity and fool-proofness.

On Plate LVII and also on the opposite page we give a number of views of Werkspoor marine Diesel engines. Figs. 1, 2 and 3 are engravings of a non-reversible Diesel engine with reversing mechanism for the screw. It has four cylinders, 400 mm. bore (15·6 in.), with a stroke of 700 mm. (27½ in.). Fig. 4 shows

DIESEL MARINE ENGINES.

CONSTRUCTED BY THE NEDERLANDSCHE FABRIEK VAN WERKTUIGEN EN SPOORWEGMATERIEEL, AMSTERDAM.

(*For Description, see Page* 634.)

Fig. 1.

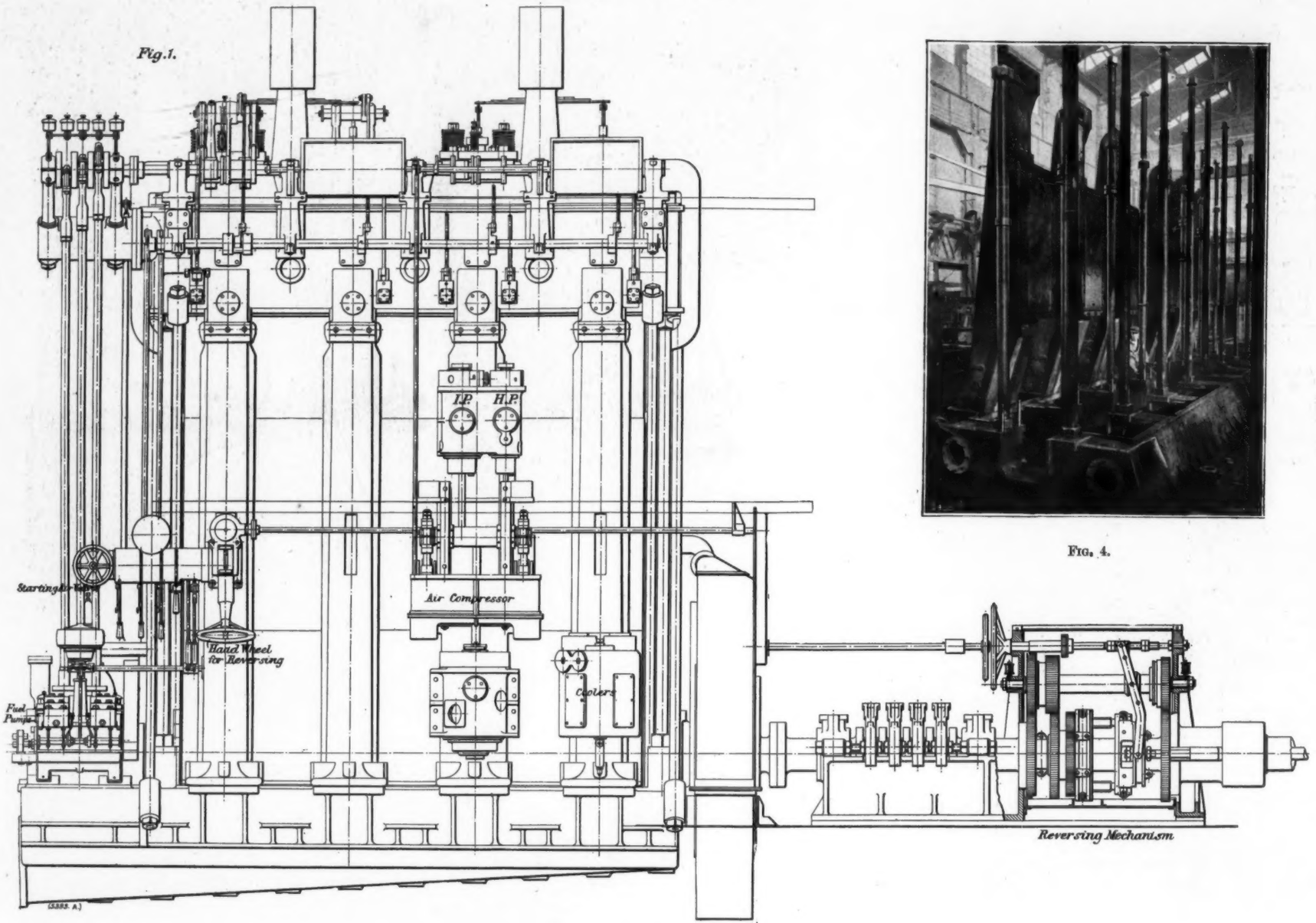
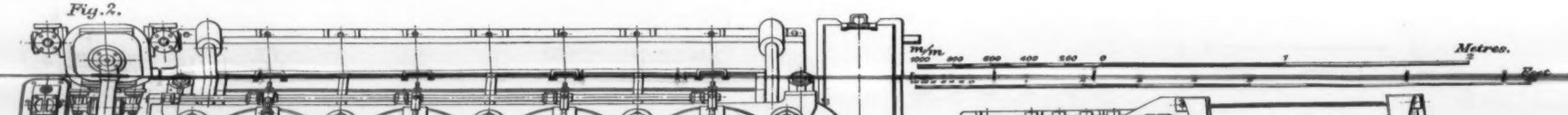
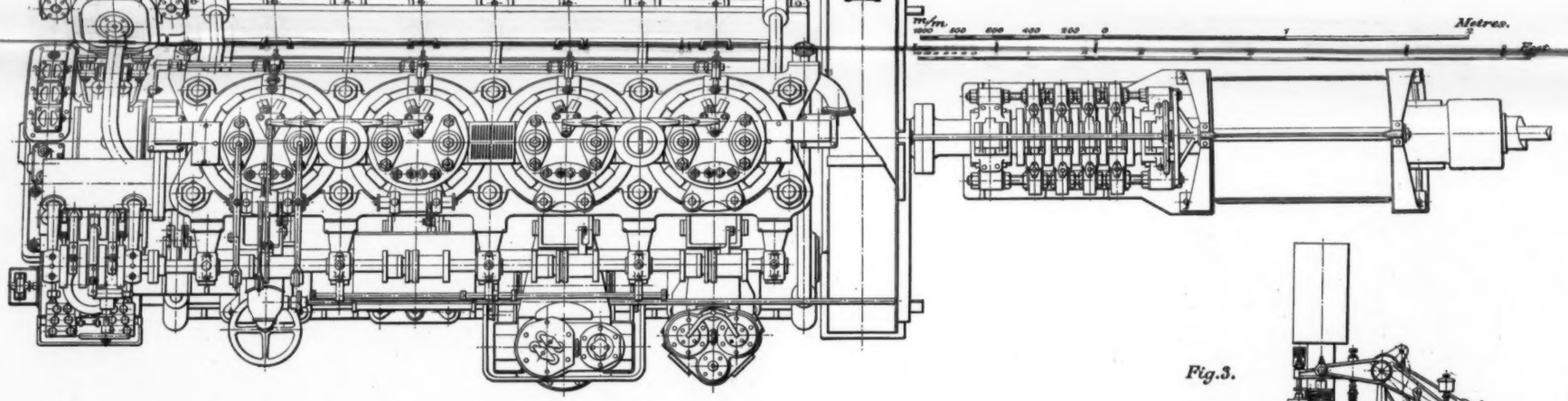


FIG. 4.

Fig. 2.




m/m.
Metres.
Feet.

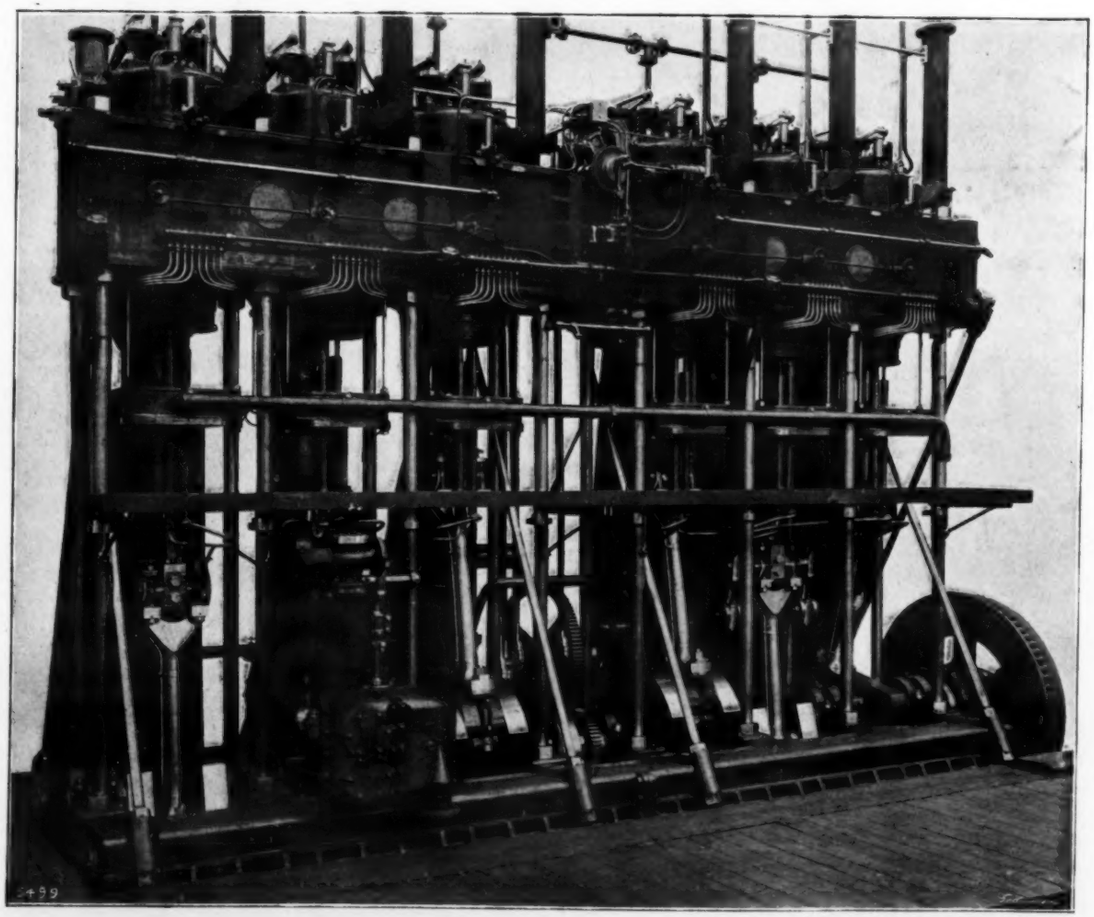
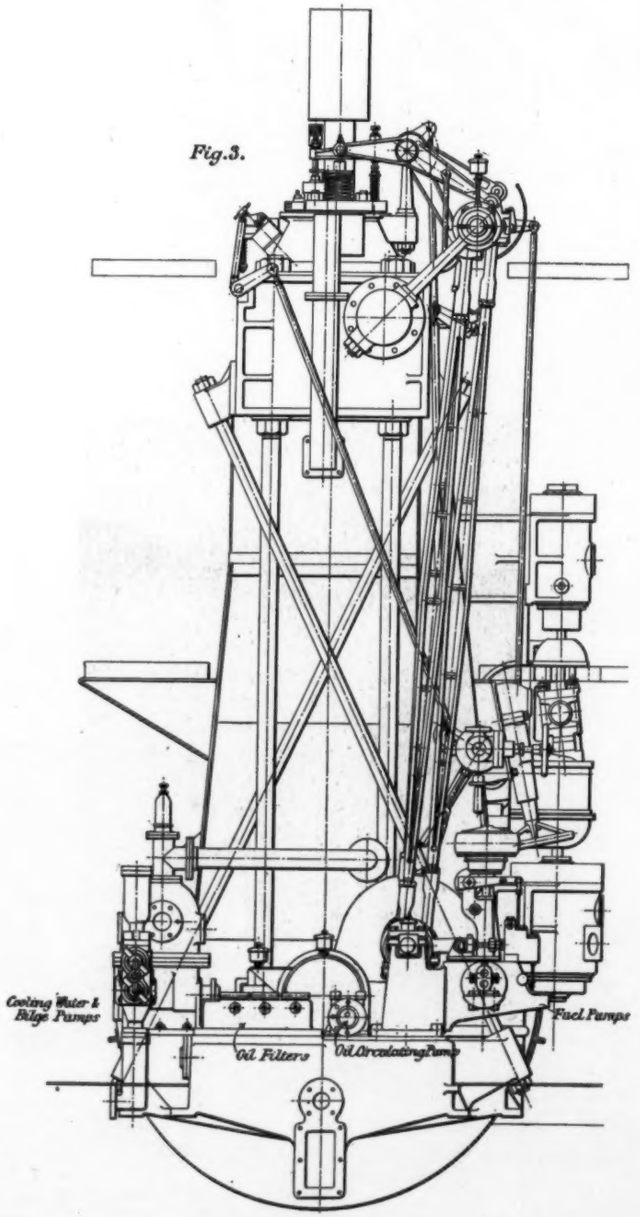


Fig. 5.

Fig. 3.


Cooling Water & Bilge Pumps
Oil Filters
Oil Circulating Pump
Fuel Pumps

DETAILS OF DIESEL MARINE ENGINES.

CONSTRUCTED BY THE NEDERLANDSCHE FABRIEK VAN WERKTUIGEN EN SPOORWEGMATERIEEL, AMSTERDAM.

FIG. 6.

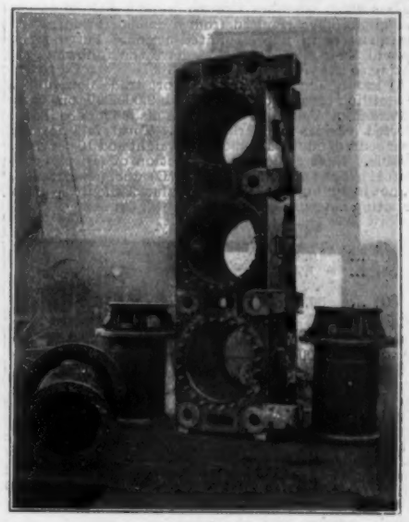


FIG. 7.

the baseplate of a six-cylinder engine with the steel stays connecting the cylinders to the bedplate. Between these stays the crosshead guide columns are placed. Fig. 5 is from a photograph of one of the motors of the twin screw set for the motor-ship Artemis, belonging to the group Ares, Artemis, Selene, Hermes, of the Anglo-Saxon Petroleum Company, each provided with Werkspoor Diesel engines of 1,700 brake horse-power. Fig. 6, on this page, shows a cylinder-box for a six-cylinder engine, with all the cylinders in it, ready to be placed on the steel stays, while Fig. 7 shows half of a cylinder-box and the loose cylinders that pertain to it. Figs. 4, 6 and 7 are parts of motors having cylinders 560 m. (22·2 in.) in diameter by 1 m. (39·3 in.) stroke, giving about 1,400 i.h.p. in six cylinders. At the time these photographs were taken 72 of these cylinders were in hand in the shops. In an early issue we shall illustrate another type of these engines.

All the Werkspoor engines have certain features in common to which attention should be drawn. These features have been adopted after consideration, and are logically founded on the fact that this type of engine is single-acting, and therefore that the stresses in the framing are always in tension, while the pistons, piston rods and connecting rods are always in compression. The tensile stresses are taken on steel bolts as the lightest means for this purpose (Fig. 4, Plate LVII), and these bolts are attached at the top to the cylinder-box (Fig. 6) and at the bottom to the bedplate as near the bearings as possible (Fig. 4). The lateral rigidity of the engine is insured by a number of diagonal rods (Figs. 3 and 5) attached at one end to the cylinder-box or beam (Fig. 6) and at the other end to the bed-plate. The general arrangement of the vertical and diagonal rods is seen in Fig. 3.

The Werkspoor motors, in the majority of instances, follow the usual marine practice of having crossheads to take the lateral pressure of the connecting rod. These run on slides carried by cast-iron frames bolted to the bedplate, and also attached to the cylinder beam in a way that permits a slight play to allow for the difference of expansion between the cast-iron frames and the steel bolts.

The cylinders of the six-cylinder engine are, three by three, combined in two cast-iron beams or boxes, forming water jackets (Figs. 6 and 7), which are connected in the middle. Thus a stiff beam or girder is formed, to which the above-mentioned steel bolts may be attached. As there are no bending stresses in the bedplate, this can be made as light as the exigencies of the foundry will allow. The cylinder beam is in this engine the main part, the spine of the engine, and not the bedplate, which is connected to the cylinder beam by means of the steel bolts. Incidentally, so to say, these steel bolts support the beam when the engine is not working.

The care of the pistons is a most important matter in all Diesel engines, and, naturally, it is much influenced by the time and trouble involved in the operation. This is specially the case with marine engines, which cannot reckon on a long week-end stoppage, as in a mill. To render inspection quite easy the cylinders of the Werkspoor motors have a detachable part which projects underneath the cylinder beam and is of such a size that when the crank is on the bottom centre the piston is entirely within the extension piece. If the piece is lowered, the piston comes into view, when it can be inspected and cleaned, and, if necessary, the piston rings can be renewed. To inspect all the pistons of a six-cylinder engine does not take more than a day. A piston can be taken out completely by loosening the bolts fixing it to its rod.

Another special feature of the Werkspoor engine is the fuel feed. All users of Diesel engines know that when an engine does not start well, or shows other irregularities, in nine cases out of ten the cause will be found in the fuel pumps. These small high-pressure pumps, with three valves each (making a total of 18 little valves for a six-cylinder engine), are too complicated to be desirable in a marine engine. The Werkspoor system does away with these pumps, and uses one pump of ample dimensions (with one spare pump) for the entire fuel supply. The valves are steel balls, which can never stick or get out of order. This pump delivers the fuel into a vessel, in which a pressure equal to the pressure in the fuel valve cages in the cylinder head is maintained. Now, this vessel is somewhat higher than the fuel valves, and the fuel flows by gravity to the valves, passing through a distributing box with regulating spindles and a hand throttle valve. As the speed of the fuel is very low, the head being small, and the flow uniform, these spindles can be of relatively large dimensions, and can be easily regulated. Even if the fuel pump should fail, the contents of the vessel will suffice to keep the engine going for a quarter of an hour, and enable the engineer to put the spare fuel pump to work.

In order to keep the fuel-vessel filled to a certain mark, it is supported by one arm of a counterweighted two-armed lever, which works a valve in the suction of the fuel pump. When the weight of the fuel in the vessel exceeds a certain limit, the vessel comes down and shuts off the valve, which is not opened again until so much fuel is used by the engine that the vessel is again lifted up by the counterweight. This device is simple and absolutely reliable. Another element of large-sized engines which has given endless trouble is the piston cooling, usually because of leaking stuffing boxes in the telescopic pipes. The Werkspoor patented system in its latest form does away with all stuffing boxes. It consists of two telescopic pipes, one being fixed to the piston, the other to the oil-tray underneath the cylinders. (Fig. 5.) In the latter the water is kept at a constant height, the former takes at each stroke a certain amount of water out of the latter, and throws it into the piston. It is discharged through a system of similar pipes. The clearance between the pipes is about half an inch, even if badly mounted or slightly bent, the pipes do not touch, which makes the device absolutely fool-proof and reliable even in the worst of conditions.

We may next direct attention to the cylinder heads which have given so much trouble in almost every make of engine. The Werkspoor cylinders are in one piece with the heads. The cooling water thus surrounds the hottest parts of the cylinder where it is most effective, whereas, in the majority of constructions heavy masses of cast-iron are found all around the cylinder top. The casting is entirely without ribs liable to crack. The fuel valve is placed out of the centre, instead of being squeezed in between inlet and exhaust valves; a more symmetrical design of the head is thus attained, and, what is more important, a considerable cooling space is left around each of the four valve cages. The four covers in the outer wall make a survey and cleaning of the interior exceedingly easy, and the formation of scale can be easily detected, and the scale removed.

Since all these improvements have been applied, cracked cylinder heads have become absolutely a thing of the past with the Werkspoor engines.

Another feature which deserves attention is the camshaft drive. The drive by means of helicoidal gear and a vertical shaft, as in stationary motors, was not deemed suitable for a marine engine. In the first place, this kind of gear wears quickly through friction, and cannot be easily replaced; secondly, the timing of the valves is thrown out if the crankshaft is shifted by the wearing of the thrust-block segments.

All the Werkspoor engines have a secondary crankshaft, driven by spur-gear at half the number of revolutions. By means of long connecting rods (Fig. 3) the movement is transmitted to the camshaft. These connecting rods are usually four in number, and so constructed that they can only be in tension. They are generally made out of a steel tube split longitudinally in the middle over the greatest part of the length. The two halves are then bent apart by stays in order to stiffen the rod up. The reversing mechanism with two camshafts, one for ahead, the other for astern, has been described several times, and is simple enough, though it is somewhat heavy, and occupies more space than is desirable. The Werkspoor are, therefore, introducing a new reversing mechanism on the engines now building.

An Aspinall governor is used to shut off the gravity fuel-flow between the high-pressure tank and the distributing box. The engine stops at once when the fuel is cut off, and, therefore, in heavy weather, runs much more regularly than a steam engine which contains much steam in the receivers which is not affected by the throttle.

(To be continued.)

GENERAL LICENCE UNDER THE SMALL TOOLS ORDER, 1918.—The Minister of Munitions gives notice that as from May 31 he authorises every person, until further notice, to manufacture for his own use, but for no other purpose, all or any of the small tools referred to in the above Order. Applications for licences to manufacture small tools for other purposes are to be addressed to the Controller of Machine Tools, Charing Cross Buildings London, W.C. 2, and marked "Small Tools."

THE ENGINEERING INDUSTRY.

FOUR Departmental Committees were recently set the task of examining and criticising the state of four sections of the engineering industry in the period before the war. Having studied the four quarters, each in isolation from the whole, the committees came to conclusions which are more depressing and less illuminating than might have resulted from a consideration of the four quarters in normal united action. Putting the totals in their related order we have the following, all relating to the year 1913.

(A) Production of coal and export trade flourishing. 73·4 million tons exported, of which 9,000,000 tons went to Germany. Coke and other fuels made from coal also exported besides bunkering coal. Total fuel formed 75 per cent. of our total exports in weight and 10 per cent. in value. Next comes the production of (B) pig-iron, (C) steel in tons and the export of (D) steel (as material, &c., not including machinery) in value of the three great competing nations :—

	Britain.	Germany.	U.S.A.
	Tons.	Tons.	Tons.
(B) ...	10,300,000	19,000,000	31,000,000
(C) ...	7,700,000	18,700,000	31,300,000
	£	£	£
(D) ...	55,300,000	54,500,000	32,600,000

(E) Next comes engineering products exported; the value of British exports was 29,300,000*l.* in 1903, which rose to 59,200,000*l.* in 1913. The corresponding figures for Germany and the United States of America are not given. In addition, there was an output of 50,000,000*l.* from British shipbuilding and marine engineering works.

The alphabetical order of arrangement we have used corresponds to the progress from mining to material and on to finished product. The figures might be better selected, but we use only those quoted by the sectional committees and the Grand Committee. When engineering is considered in its national aspect it must be taken as a whole: mining, smelting, rolling, machine, engine and ship-making industries, are, from the national point of view merely stages of one continuous process. From that aspect the figures show that: (1) In mining we hold our own, that (2) in material-making we lost pace with our competitors, having given Germany much of our mining advantage, and (3) that in the final and highly-skilled work we more than held our own. These results prove that our engineers maintained a long, severe struggle against formidable rivals, and maintained it with success. It did not need four committees to tell us that in the matter of material, design and workmanship British engineers need not fear competition. All that individual effort can do we can accomplish. But in some forms of business individualism is at a grave disadvantage in the face of a combination, and it is just in these that we have made little or no progress. An American defined strategy to be the art of getting the greatest number of men on a given spot at a given time, and we have recently seen that the Germans are fairly successful in this. There is also strategy in business, but it cannot be practised to any extent unless some person or body can exercise control over the rest. It is in this respect that we have been deficient as business men.

CEMENT MORTARS AND MAGNESIUM CHLORIDE.—Some experiments on the influence of magnesium chloride on cements to be used in frosty weather were made last winter by the Verein Deutsche Portland-Zement Fabrikanten. Some specimens were mixed with standard sand in the proportion 1 : 3 and either with ordinary water or with an aqueous solution of magnesium chloride. The specimens were exposed to a cold of — 7 deg. C. (about 20 deg. F.); the ordinary specimens took three days to set sufficiently for removing the mould casing, the specimens prepared with $MgCl_2$ set within one day. On the other hand the strength tests, performed after one week and four weeks, were in favour of the cement made simply with water; the values found were 185 kg. and 205 kg., and 295 kg. and 344 kg. per square centimetre respectively. Thus the addition of $MgCl_2$ lowers the strength of the cement somewhat, not sufficiently, however, to exclude the use of this reagent when cement has to be laid down during cold weather.

THE COMMERCIAL MOTOR USERS' ASSOCIATION.—Colonel R. E. B. Crompton, C.B., has been elected first president and first life member of the Commercial Motor Users' Association. Since 1903 he has been chairman of the General Committee, but pressure of other engagements has obliged him to relinquish the post. The association have therefore elected him as president to mark their appreciation of the great work he has done for heavy road traction, and to signalise the event a luncheon was held in his honour last Friday, at the Royal Automobile Club. So long ago as 1861, Colonel (then Mr.) Crompton commenced building a steam wagonette, which attained a fair amount of success on the road. Later, as a military man in India, he was appointed Superintendent of the Government Steam Train to carry out an extended experiment with road locomotives on the Grand Trunk road in the Punjaub. Later, in the South African War, Colonel Crompton made excellent use of traction engines, and so impressed General Roberts that he was sent home to start the Mechanical Transport Committee, on which he served for five years. Ever since he has been an ardent advocate of heavy mechanical traction as a means of collecting and distributing merchandise for and after railway transit. Mr. E. T. Shrapnell Smith is now the Chairman of the General Committee.

NOTES FROM THE NORTH

GLASGOW, Wednesday.

Scotch Steel Trade.—Although ordinary mercantile consumers are now getting some consideration and a small proportion of the steel output, the production of war material goes on with considerable briskness. The pressure at the works is not quite so intense as it was, and there are indications that some further improvement may shortly be expected. If this is to be relied upon much of the trouble experienced by steel manufacturers will be obviated. Meantime, however, every effort is concentrated upon the prompt deliveries of the ship-building and sectional material required for Government contracts, the demands in this connection still being exceptionally heavy. High priority claims are being dealt with at many of the works, and the urgency of these demands cannot be lightly set aside. There is a chance that in the near future some alteration in the price of billets may take place which would be distinctly advantageous to steel makers. If this change can be put into effect and a sufficient supply be obtainable the conditions of production would certainly be on a more satisfactory basis. Limited shipments to France and India represent the export trade at the moment.

Malleable Iron Trade.—There is no lack of business in the malleable iron works, the order books still being so well filled as to warrant the statement that it will take many months to work them all off, even supposing that no additions were made in the interim. This contingency, however, is not likely to happen. Constant activity goes on therefore, in both the iron and steel departments, and the difficulty of satisfying the more urgent claims is, at times, a matter of serious consideration.

Scotch Pig-Iron Trade.—The demand for pig-iron of all grades is unabated, hematite for the steel works being much in request, with forge and foundry qualities not far behind, so that business is certainly flourishing. Despite the large output, however, there is scarcity of some brands owing to the fact that many blast furnaces have been turned on to the production of basic quality. In the meantime everything produced is rapidly absorbed locally.

COMPOSITE INSULATING MATERIALS INVESTIGATION.—A Joint Committee representing the Institution of Electrical Engineers and the British Electrical and Allied Manufacturers' Association appointed under arrangements with the Department of Scientific and Industrial Research, have been considering a draft specification applicable to composite insulating materials used for electrical work in general. A second specification covers that type of vulcanised material which is used for magneto distributors. The committee would be glad if manufacturers of composite insulating materials (other than vulcanised materials), who are at present in a position to supply samples of such materials, would be so good as to communicate with the secretary of the Institution of Electrical Engineers, with the object of tendering—unless they have already done so.

TRADE WITH CANADA.—The Expert Association of Canada, Limited, 62 to 65, Charing Cross, S.W. 1, has issued a list of the principal manufactures which it is able to supply, including metals, railway rolling-stock and railway material, machinery, tools, &c. The association asks that intending purchasers send in their requirements so that it may be in a position to quote, adding that while Atlantic shipping space is at present difficult to arrange, it is from time to time able to secure a limited amount of tonnage; as facilities are increased, clients will be given every benefit available. Pacific shipping conditions being easier, a fairly regular service is available to New Zealand, Australia, Japan and China. In addition to obtaining freight, the association arranges insurance, financing of orders, and extends every possible facility in the interest of clients.

RUBBER VULCANISATION BY SELENIUM.—Mr. Charles R. Boggs, of the Simplex Wire and Cable Company, Boston, Mass., has obtained a certain amount of success with vulcanising rubber by means of selenium since 1913. Previous attempts by others had not been successful. Selenium stands chemically next to sulphur, but is more metallic and has a higher melting-point, 217 deg. C., and higher atomic weight, 79·2, against 118 deg. or 140 deg. C. (two modifications) and 32 for sulphur. There are three modifications of selenium, but the two amorphous pass into the black crystalline modification (near 150 deg. C.), which is the one used in selenium cells because light lowers its electric resistance. A partial vulcanisation was obtained by heating rubber and this selenium up to 150 deg. C. for a couple of hours (*Journal of Industrial and Engineering Chemistry*, February, 1918). The proportion of selenium was equivalent to the amount of sulphur used for vulcanisation. When twice that amount was used, the rubber expanded by 25 per cent. when warm, but it deteriorated, whilst the former aged well. With the aid of organic accelerators a vulcanised rubber was produced, by heating at 135 deg. C. for twice the time sulphur would require. This was softer than the sulphur-rubber, and of lower dielectric strength, but of normal tensile strength and elongation. The best samples, though less strong mechanically, did not deteriorate in four years, which is remarkable considering the sensibility of selenium to light and the high temperatures used, though these temperatures were far below the melting-point of selenium. The chemical examination of the products is difficult, because selenium is far less soluble in acetone, chloroform and carbon disulphide than sulphur is.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Recruiting and Industry.—The effect of the comb-out on Sheffield industries is gradually increasing. Not only has the *personnel* of works in the city been drawn upon, but local trade is beginning to feel the influence of the withdrawal of men from other industries whose principal needs are intimately connected with Sheffield activities.

Iron and Steel.—One of the most notable features of the busy trade conditions is the active request for acid open-hearth steel. The bulk of the orders are for munitions. Very little basic steel is being produced in this neighbourhood, and users are being compelled to rely on South Wales and the Cleveland district for fairly big supplies. There has been no improvement in the supply of scrap. One department of trade which is characterised by marked briskness is the manufacture of files. In this quarter the oversees orders are normally on a big scale, but there has been created a home demand which more than makes up for the falling-off in business arising out of the export restrictions. The construction of aircraft is requiring a vast amount of files, particularly the smaller types. Manufacturers are having the greatest difficulty in coping with the situation, because of the inadequate supply of labour, and the continued calling-up of eligible men.

South Yorkshire Coal Trade.—One seeks in vain for improvement in the coal trade. Indeed, it is difficult to see how there can be any change in the immediate future, at least. Best steams are scarce. Cobbles, nuts and slacks are in keen request, but there is practically no small fuel for open sale, the whole output being destined for contractors. In the household section arrears continue to accumulate in the order books. Short supplies come forward and there is a general shortage at the local depots. There is a big demand for cokes, and maximum prices are easily obtained. Nominal prices at the pit are as follow :—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.*; best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; small nuts, 17*s.* 6*d.* to 18*s.* 6*d.*; Yorkshire hards, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire hards, 17*s.* 9*d.* to 18*s.* 9*d.*; best slacks, 14*s.* to 14*s.* 6*d.*; seconds, 13*s.* to 13*s.* 6*d.*; smalls, 9*s.* to 10*s.*, per ton at the pit.

"SAFETY FIRST."—A conference is to be held at the Egyptian Hall, Mansion House, on Wednesday, the 12th inst., at 4 p.m., to inaugurate an industrial "Safety First" campaign for the United Kingdom. The Right Hon. Lord Leverhulme will preside, and will be supported by the Right Hon. G. H. Roberts, M.P., Minister of Labour, the Right Hon. Lord Aberconway, P.C., Mr. W. Joynson-Hicks, M.P., Mr. Charles Duncan, M.P., and other prominent representatives of industry and labour.

THE RÖNTGEN SOCIETY; PHOTOGRAPHIC ACTION OF X-RAYS.—At the annual meeting of the Röntgen Society, held last Tuesday, Mr. N. E. Luboshey made a communication on the "Photographic Action of X-Rays." It was to be a demonstration, but he was called upon at so late an hour that he had to limit himself in his remarks. In ordinary photography, he pointed out, the image was confined to the surface of the film; in X-ray work it was embedded in the whole thickness of the film, which was very rich in silver salt, and one image was really piled upon the other. Thus one did not obtain all the detail that was really in the image, and the plate manufacturers were doubtful as to the instructions to give. It was bad practice to look whether the image had been formed, because nothing could be seen unless the conditions allowed fogging, and bad also to develop horizontally with strong reagents. He had developed 10 plates which he had received from Dr. Russ, one of the honorary secretaries, all simultaneously and for the same period of 22 minutes, in a vertical tank into which he inserted the plates vertically through the slots in the inner cover; the tank was air and light tight, but was inverted several times during the development. He had diluted the developer which, in ordinary practice, would have been used only for 5 minutes, with six times its bulk of water. The plates had been exposed for 2, 4, 6, 8, 10 . . . 45, 60 seconds respectively to the rays of a new Coolidge tube; what would be normal exposure with this tube was not known, but some plates would be considered under-exposed, some over-exposed; Mr. Luboshey had not been informed of the conditions of exposure. All the plates (photographs of a hip joint) were pronounced by members to be very good, except those of exposures of 2 seconds and 4 seconds; looking through these two held together, however, Mr. Luboshey observed all the detail as on the 15-second plate, and the detail was evidently present in all the plates, no matter how long the exposures. The use of strong developers and of bromide retarders really accounted for much that was ascribed to "secondary radiations"; the merits of the vertical (*versus* horizontal) tank and of strong developers are, of course, controversial points. Mr. Luboshey also showed tintometers built up of strips of various materials superposed in steps; optical glass, he found, made good tintometers; 2 mm. of lead glass absorbed as much as 1½ in. of aluminium foil. The meeting, we should add, elected Dr. C. B. Batten, president for the coming session, and at the end of the formal proceedings Mr. J. H. Gardiner, a past-president of the society and for fifteen years editor of its journal, was presented with a camera in recognition of his manifold and faithful services. Mr. W. F. Higgins is the new editor.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The market is quite cheerful, and a fair amount of home business in Cleveland pig-iron is still passing, though the allocations for foundry quality for this month have been now practically all issued. They are on a most liberal scale. Demand for forge iron keeps good, notwithstanding that recent good deliveries have enabled consumers to accumulate some stock. Facilities for distribution are still steadily improving. Trucks are much more plentiful, and considerable deliveries are being made by lighters and small coasting vessels. The adoption of the priority system for consumers in Scotland is reported to be working satisfactorily, practically all holders of Class A certificate being assured of supplies. As regards export trade, tonnage is now coming forward quite freely, and there seems some prospect of reducing arrears under existing licences. A few parcels have been despatched to Italy, and shipments to France are maintained. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are 114*s.*, and No. 1 is 119*s.*

Hematite Iron.—Rather better account can be given of the situation in the East Coast hematite branch. Supplemented by supplies of basic iron, and scrap, home customers' needs are receiving adequate attention, and more hematite is becoming available for export. Mixed Nos. of hematite are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for export to France and Italy.

Manufactured Iron and Steel.—All departments of the finished iron and steel industries are characterised by great activity. Manufacturers are working at full pressure in their efforts to cope with the enormous requirements of the Government, and the huge needs of the shipyards. Values all round are very firm. To home customers common iron bars are 3*l.* 17*s.* 6*d.*; best bars, 14*l.* 5*s.*; best best bars, 14*l.* 12*s.* 6*d.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel hoops, 17*l.* 10*s.*; and heavy steel rails, 10*l.* 17*s.* 6*d.* There are no fixed prices for export, but approximately they may be given at 2*l.* to 3*l.* per ton above the home quotations.

Tees Iron and Steel Shipments.—During May, 31,599 tons of pig-iron were shipped from the Tees. Whilst this quantity is 4,252 tons less than the April clearances, it is above the shipments of any other month of the current year. Of the May despatches, 26,277 tons went to foreign ports, and 5,322 tons coastwise. Manufactured iron loaded last month was returned at 768 tons, 678 tons going abroad and 90 tons coastwise; and clearances of steel amounted to 6,976 tons, of which 5,578 tons went abroad, and 1,398 tons coastwise. Thus May shipments of manufactured iron and steel totalled 7,744 tons, or 1,553 tons above the April clearances, but considerably below the total of any preceding month this year. The total shipments of pig-iron, manufactured iron and steel last month amounted to 39,343 tons, as against 42,042 tons in April, 35,574 tons in March, 37,518 tons in February, and 51,718 tons in January.

Coke.—Demand for coke is heavy and supply is scarce. As yet, however, though some consumers are not receiving quite adequate supplies, no very great inconvenience is experienced from the shortage. At the same time, it is fully realised that in the very near future much difficulty may be found in dealing with the situation. For home use, foundry quality is 38*s.*, average blast-furnace kind 33*s.* at the ovens, and low phosphorus sort 35*s.* 6*d.* at the ovens. For shipment to neutrals the lowest price named is 50*s.* for both foundry and furnace coke, and transactions are few.

THE ASSOCIATION OF BRITISH MOTOR AND ALLIED MANUFACTURERS, LIMITED.—The annual general meeting of this association was held on Thursday, May 23. Mr. Manville, who has been president of the association since it was reorganised, was unable to stand for re-election, having taken up the important duties of President of the Association of Chambers of Commerce of the United Kingdom. In proposing the adoption of the report and balance sheet, Mr. Manville referred in detail to the work done by the association, emphasising its present utility to the industry and its great possibilities of future usefulness. The balance sheet and report were unanimously adopted. Mr. H. C. B. Underdown was elected president for the ensuing year. Mr. Underdown is chairman and managing director of Commercial Cars, Limited, and a director of Sheffield Simplex Motor Works, Limited. He is also chairman of the Motor Industry Branch Committee of the Engineering Trades Committee of the Ministry of Reconstruction, and at present holds the position of Director of Agricultural Machinery at the Ministry of Munitions. He has for the past two years been chairman of the Commercial Vehicle Section of the association. Mr. Bernard Caillard was elected vice-president for the ensuing year. Mr. Caillard is a director of Wolseley Motors, Limited, and managing director of the British Lighting and Ignition Company. In the latter capacity he has for the past year been chairman of the Accessories and Components Section of the association. He is also vice-chairman of the Motor Industry Branch Committee. The association is now very fully representative, receiving the almost unanimous support of the British motor industry. This is important in view of the fact that the Government frequently desires to take the opinion of institutions fully qualified to speak for various British industries.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—At present there is a general shortage of coal, and there is little prospect of an early mitigation of the existing conditions. Salesmen are complaining of the poor outputs they are getting from the collieries. Diminished production was expected as the result of the comb-out of miners for military service, but the loss is stated to be more than proportionate to the withdrawal of labour, and the inference is drawn that the men are not working with the vigour and skill of which they are capable, and which it is reasonably expected they would exercise under the impetus of war crisis. This does not imply disloyalty, but rather a want of thought and knowledge. It is proverbial on the South Wales coalfields that when wages are high outputs are relatively low. Then, again, the beautiful weather which prevails has a tendency to increase absenteeism. The authorities are lifting all the coal that is now reaching the market, and private trading has, for the moment at any rate, practically ceased to count. There are occasional inquiries on the markets for Spanish and other neutral destinations, but it is a matter of extreme difficulty to obtain the release of coal for these destinations, and prices continue, therefore, to rule around the scheduled figures. The scarcity of smalls, too, is now almost as acute as that of large coals, and where labour is available some of the banked smalls are being worked off.

Newport.—Although the strikes in the Monmouthshire coalfield are over, the collieries in the Eastern and Western Valleys are not yet working satisfactorily, and supplies are considerably below the normal. Black Veins are in strong demand as well as the better classes of locomotive coals, while for washed smalls there is an acute shortage.

End of the Strikes.—As indicated last week the strike movement in the Monmouthshire coalfield consequent upon the dispute at the Tredegar Collieries assumed serious proportions. There was absolutely no reason for these outbreaks and they were engineered unquestionably by what are known as the "reform" leaders, who are a band of ambitious men—mostly young men—who do all that they can to undermine the authority of the recognised leaders. Their following is not by any means great, but it is the experience in the South Wales coalfield that a few men, who are so bent, can do a deal of mischief. The leaders were confident of being able to deal with the situation, but unfortunately this would require a little time, and the demand for coal was urgent. To their credit be it said that they waived their own interests and risked their own position rather than prolong the struggle. Instead of compelling the men to accept the terms they had approved of and recommended to the men, they agreed to the proposals of the Coal Controller, which really meant that the disaffected section were to get practically everything that they demanded.

COMPRESSIBILITY OF NATURAL GAS.—As all natural gases are mixtures of several gases or vapours, they vary as to their compressibility, which is a fact to be taken into consideration when the gases pass through volume-meters. In Technical Paper 158 of the United States Bureau of Mines, J. A. Burrell and I. W. Robertson show that the compressibility can, with sufficient accuracy, be calculated from the composition of the gas. The paper deals in particular with the natural gases from nine cities of the United States. The main constituent is generally methane CH_4, nearly all contain also ethane C_2H_6, of which about 15 per cent. occur in the natural gas from Cleveland (Ohio) and from Los Angeles, California, 22.5 per cent. in the gas from Charleston, W. Virginia, and 59.5 per cent. in the gas from Olney, Illinois; further nitrogen (up to 8.4 per cent. in Kansas City gas) and carbon dioxide, generally less than 1 per cent., but 25 per cent. in the Los Angeles gas; the Olney gas further contains 1 per cent. of sulphuretted hydrogen. Having determined the compressibilities of these various constituents (specially prepared pure gases) for pressures up to 40 atmospheres, the calculations are made as follows. Buffalo gas, *e.g.*, contains 88.1 per cent. of CH_4, 11.4 per cent. of C_2H_6, and 0.4 per cent. of N.; the partial pressures at 40 atmospheres of these gases are hence: $p_1 = 0.881 \times 40 = 35.2$; $p_2 = 0.115 \times 40 = 4.6$; $p_3 = 0.004 \times 40 = 0.2$. With regard to compressibility there is no perfect gas, *i.e.*, the volume does not quite vary inversely as the pressure; if we except hydrogen, all gases first compress more than a perfect gas would do, as the pressure is increased to a certain value, which is different for different gases, but generally lies above 50 atmospheres. [When the pressure is further increased, the compressibility becomes more and more less than that of a perfect gas, but this point does not concern us now, because we only deal with pressures up to 40 atmospheres.] The product pv hence has not a constant value, which Burrell and Robertson express as 100 per cent., but a smaller value, and the deviative is for CH_4. $a = 0.228$ per cent. per atmosphere, for C_2H_6 $b = 0.9$ per cent., for nitrogen $c = 0.01$ per cent.; hence the total deviation is $D = ap_1 + bp_2 + cp_3 = 12.17$ per cent., and the compressibility of the Buffalo gas is $100 - 12.17 = 87.83$ at 40 atmospheres. For a pressure of 20 atmospheres, the compressibility would be 93.9, and in the case of the Charleston, Los Angeles, Olney gases, the calculated (and observed) values are 92.5 (93.6), 91.4 (92.2), 87.6 (87.7). The agreement between the calculated and observed compressibilities is thus fairly satisfactory. The paper also contains a table on the compositions of 22 other natural gases, in which we notice the gas from McKean, Pennsylvania; this gas consists of 67 per cent. of ethane, 2.3 per cent. of methane, and 0.7 per cent. of nitrogen.

NOTICES OF MEETINGS.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, June 8, at 2.30 p.m., in the Heriot Watt College, Chambers-street, Edinburgh, the following papers will be discussed: "Capital Charges Contrasted along with Current Expenses," by Mr. David M. Mowat; "Stripping and Re-lining a Shaft at Cowdenbeath, Fife," by Mr. Henry Rowan; "The Occurrence of Coking Coal in Scotland," by Mr. Robert W. Dron; "Education (Scotland) Bill," by Mr. William Jarvie. A paper will be read on "The Repair of a Circular Shaft of Small Diameter," by Mr. Stewart Chambers.

THE SOCIETY OF ENGINEERS (INCORPORATED).—Monday, June 10, at 5.30 p.m., in the Apartments of the Geological Society, Burlington House, Piccadilly, W. a Special Lecture on "War On and Under the Sea" will be delivered by Mr. Edwin Hall, Chief Lecturer to the Navy League.

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS.—Tuesday, June 11, at 2.30 p.m., at the Midland Grand Hotel, St. Pancras, Mr. Thorrowgood will reply to the discussion on his paper, and afterwards a discussion will take place on the following paper: "A Graphical Method of Solving D.C. Track Circuit Problems," by Mr. H. M. Proud, Associate Member.

THE JUNIOR INSTITUTION OF ENGINEERS; NORTH-EASTERN SECTION.—Tuesday, June 11, at 7.15 p.m., at the Mining Institute, Neville-street, Newcastle-on-Tyne. "The Applications of Static Transformers," by Mr. S. A. Stigant.

THE PHYSICAL SOCIETY OF LONDON.—On Friday, June 14, at 5 p.m., at the Imperial College of Science, Imperial Institute Road, South Kensington, S.W., a discussion will take place on "The Teaching of Physics in Schools," to be introduced by Sir Oliver J. Lodge, Principal of the University of Birmingham. Contributions to the discussion are expected from: Mr. C. E. Ashford, M.V.O., Headmaster R.N. College, Dartmouth; Dr. T. J. Baker, King Edward's High School, Birmingham; Mr. C. L. Bryant, M.A., Harrow School; Mr. G. F. Daniell, Educational Department, London County Council; Professor R. A. Gregory, Chairman of the British Association Committee on Science in Secondary Schools; Mr. J. Nicol, B.Sc., Northern Polytechnic, Holloway; Professor T. P. Nunn, London Day Training College; Mr. F. W. Sanderson, M.A., Headmaster, Oundle School; Mr. A. T. Simmons, B.Sc., A.R.C.Sc., editor of the *School World*; Mr. E. Smith, B.Sc., Leyton Secondary School; Professor F. Womack, Bedford College. Visitors are invited to attend this meeting of the society.

THE INSTITUTION OF MINING ENGINEERS.—Thursday, June 13, and Friday, June 14, in the Rooms of the Geological Society, Burlington House, Piccadilly, London, W. 1. Thursday, June 13:—11 a.m.: The following papers will be read, or taken as read: (1) "Terrestrial Magnetism in Relation to Mine Surveying," by Dr. Charles Chree, F.R.S., Superintendent of the Central Observatory of the Meteorological Office at Richmond (Kew Observatory); (2) "The Effects of Dust-inhalation," by Mr. John Scott Haldane, M.D., F.R.S., Director, Doncaster Coal Owners' Laboratory. The following papers, which have already appeared in the Transactions, will be open for discussion: (a) "The Oxidisable Constituents of Coal.—Part I.," by Mr. J. Ivon Graham—vol. liv., page 197; (b) "American Notes," by Mr. Samuel Dean—vol. liv., page 225. 1 p.m.: An adjournment will be made for luncheon. 2.30 p.m.: The general meeting will be resumed. Friday, June 14:—10 a.m.: The following papers will be read, or taken as read: (3) "The Origin of Blackdamp," by Mr. J. Ivon Graham, Chief Chemist at the Doncaster Coal Owners' Research Laboratory; (4) "The Flow of Air through Small Coal and other Broken Material," by Mr. J. T. Storrow, Chemist at Brodsworth Colliery.

DETERMINATION OF NITROGEN IN EXPLOSIVES.—Most explosives being some nitro, or nitroso, substitution products, the quantitative nitrogen determination in explosives and materials for their preparation is an important analytical operation. The determination can be effected by several methods which are not equally reliable under different conditions, however, and not equally convenient. A critical comparison of the chief methods was recently conducted by W. C. Cope and Guy B. Taylor, of the Bureau of Mines (Technical Paper 160). The Dumas method is considered generally applicable to all classes of organic substances and is found to be so, but it is also laborious and requires time and great care. The substance is mixed with cupric oxide and copper gauze and heated to 950 deg. C. in a silica-glass tube, first in a vacuum, and finally in a current of carbon dioxide; the nitrogen is collected as such over caustic-potash. One of the difficulties is the preparation of a cupric oxide free of nitrogen. In the Kjeldahl method the nitrogen compounds are reduced to ammonia which is liberated and determined, and in the modification of the method by Jodlbauer and Gunning this reduction is effected by means of zinc dust. The Chenel method effects the same reduction by the acid of phosphorus iodide. When nitrogen is present as a nitrate, inorganic or organic, the nitrometer method of Lunge or of Du Pont is used; the substance is dissolved in sulphuric acid, and the NO liberated is determined volumetrically; the Du Pont apparatus is more complicated than the Lunge apparatus, but the calculations are simpler. Twenty of the 43 pages of the paper are taken up by tables for the use of the Lunge nitrometer; they are compiled by B. Trexler and C. R. Borland, of the American Smokeless Powder Company.

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(*For Description, see Page 634.*)

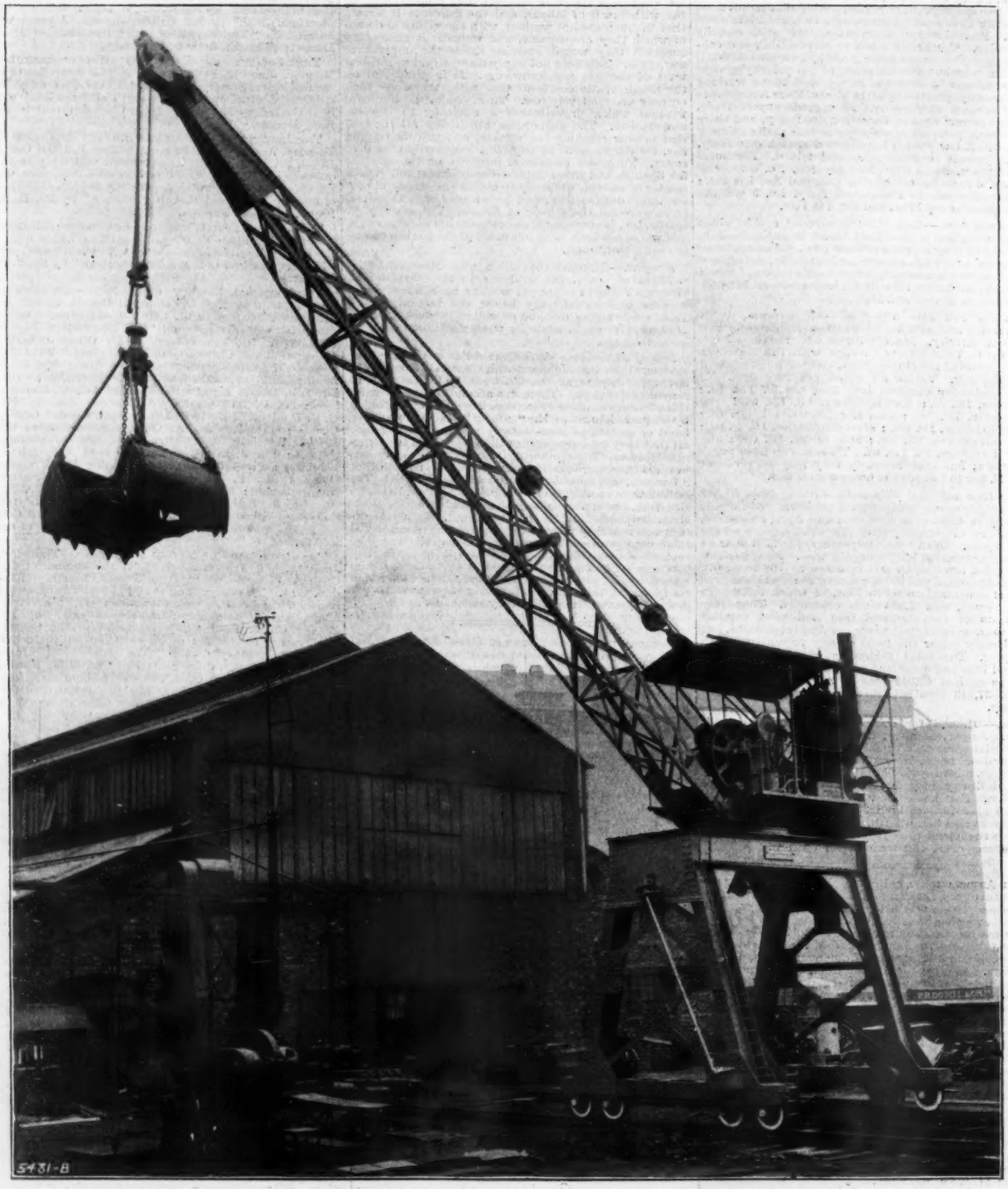

FIG. 3.

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With a Two-Page Plate of the DIESEL MARINE ENGINES.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 637.

ENGINEERING.

FRIDAY, JUNE 7, 1918.

WASTAGE—A CRIME.

AMONG many other valuable services rendered to the community at large, it is the constant aim of the engineer to multiply human effort, and at the same time effect vast economies. Most invention either increases convenience or limits wastage. As time passes the place of the engineer as the great conservator and guardian of natural resources becomes more and more evident. In the main the production of raw material is not his chief activity, indeed the engineer in most fields has to deal initially with semi-prepared material, yet due thrift in utilising the bounty of Nature is a matter which he never forgets. The means whereby Nature is laid tributary to man in every case involves the efforts of the engineer who provides mechanism and means to the actual producer.

It should be remembered that the raw material of many industries, and important ones at that, does not of necessity involve depletion of resource. The initial material may be controlled, increased or diminished at will and where it is of animal or vegetable origin it is obvious that supply may be multiplied by due effort and can be controlled in many ways.

The case is otherwise with mineral resources; every unit won diminishes the absolute available total, for whatever may be the case elsewhere man is unable to replace mineral wealth whatever his desire. There are many opportunities open whereby advantage can be taken of natural resources otherwise wasted; wind motors and propulsion by wind in the case of ships, the utilisation of natural water power which grows more prominent year by year, and others may be cited. Timber, cordage, textiles, food, all these may be controlled by conservation and wise policy; these raw materials are in process of daily renewal and can and may be increased by labour and cultivation.

Iron, coal, and mineral oil, upon which modern civilisation depends are irreplaceable; whatever their initial quantity every ton utilised leaves one ton less to come. It is therefore less reprehensible to waste material of vegetable and animal origin than minerals, although actual practice shews the direct contrary to be usual. Many a smile has been caused by speculative estimates of the time when total exhaustion of coal, for example, shall leave a future generation shivering for its lack. However distant the prospect may be such exhaustion must inevitably come.

The modern world is spending royally resources not of its production, squandering with both hands the almost priceless gifts of geologic formation, regardless of eventuality and finding only the inconvenience of rising prices due to increased demand and the greater difficulty of supply. At the present time consumption and production are at a maximum relative to the available labour. The special conditions have imposed a check salutary in many ways upon spendthrift wastage. It is to-day unpatriotic, if not criminal, to waste anything needing human effort or sustaining human life. The circumstances may have eventual benefit in making prominent the fact that wealth and thrift consist largely in limiting our desires. A time of hardship has also shown that for many hitherto indispensable things rational substitutes may be found.

This period of crisis and emergency having enforced thrift upon the least willing should give rise to profound thought and the contriving of expedients to limit wastage in more normal times. It is the special hallmark of the engineer that, more than most men, he is privileged to limit waste; as time passes he contrives to extract a nearer approach to maximum value from original supply. The realm of fractional values is almost wholly his own field of effort. The monetary gain is a spur to effecting conservation and every gain thus made defers the period of total exhaustion. Every piece of mechanism has for its object the saving of human endeavour, in other words the elimination of waste human effort. Organisation is also in the interest of human thrift; its main purpose is to produce results with the least expenditure of effort. Standardisation and specialisation have more or less the same objectives—increased production, diminished cost or lessened wastage of effort or material. The true economist of the present era is the engineer; everything he does lessens wastage in some form or other, yet while every other aspect of his work receives notice, this seems to escape prominence. The engineer is the custodian of mineral resources of the most vital kind and the more this is realised the better.

Inefficiency is waste; idleness or unemployment is waste; ill-done or ill-conceived work is waste, human misfits involve waste; there is wastage of human energy at both ends of the social scale due to contrasting sets of reasons. The wastage due to stupidity is incalculable, it out-tops the waste involved by theft or rascality. Co-ordinated effort is the greatest preventative of waste yet invented, and in some quarters is the most resented of all modern innovations. Waste cannot be afforded by the most affluent, for no initial fortune is inviolable to the spendthrift. Every man who clings to worn or out-of-date machines or processes, when better are available, sins against the light; and makes the community pay penalty for his default; he is in deed and fact squandering the common fortune. If he be a monopolist exercising privilege in restraint of improvement to augment profit, he commits a crime against the human species.

Among the outstanding future problems which must be tackled by the future Government is that of conserving national resources. No nation ought to throw away the natural wealth it took millions of years to store for beneficial purposes, by wasteful or uneconomical methods. We are now in the mood, because of the discipline of circumstance, to consider wastage as a criminal proceeding. Not a word can be said against rightful exploitation, but use must justify itself lest want make us wise. We take and leave at pleasure all provided by the foresight of Nature, forgetting that to plant a tree when one is cut for timber is more than simple precaution against future want—it is a bounden duty.

Scrap should be treated with the utmost respect; it cost toil to win originally, and it will have an honoured place when duly treated for future use; it is treated with more deference at the moment than ever before, while the interval between disuse and reuse grows steadily less. Metallic wastage, although considerable, is slight in comparison with that of coal and oil which are totally expended when utilised. The time is near at hand when the problems of waste will attract universal attention rather than occasional speculation; results will be judged not alone in terms of coin but as utilising the otherwise destroyed. Industry is the dominant feature of the present era, wastage its most regrettable accompaniment, large amounts of which are in the nature of preventable decay.

There is, perhaps, a type of thrift whose results are too dearly bought; often it is only by incurring vast expenditure that economy can eventually be secured. The relation of expenditure as investment,

to expenditure earning no return is rather a complex matter. The nation which saves on education by stint is not to be envied, nor is the man generous who lavishes entertainment on his friends and leaves his dependents a public charge. Wastage limits national power, paralyses effort, causes insolvency. How many bye-products have given greater returns than the objective business are matters of current knowledge.

Conservation of natural wealth, restoration of replaceable resources, utilisation even at enhanced cost of power to be had for the taking, these are primary to national well-being, cardinal to humanity at large. Wastage is crime, inefficiency is deplorable, stupidity deserves neither extenuation nor pardon; all three are to a great extent preventable.

GUN EROSION.

In the suggestive and instructive paper read last March before the Institute of Naval Architects, Professor H. C. H. Carpenter explained how the working out of the iron-carbon equilibrium diagram had rationalised the whole question of the heat treatment of steel, rendering intelligible and co-ordinating numerous practical rules and recipes. These, in the absence of the definite guidance now furnished by the laboratory researches of many notable metallurgists, had been arrived at, by following the apostolic precept of trying all things and holding fast to that which had proved good. It is indeed remarkable how much can be accomplished in this way, but the method, though effective, is slow and costly. In fact, the mathematical theory of probability affords some ground for the view that the advance made is in such cases proportional to the square root of the effort expended, in place of being directly proportional thereto, as should be the case in investigations carried out under the guidance of a definite and approximately accurate theory.

The problem of the erosion of guns affords a striking illustration of how a vast mass of observations may be accumulated as the result of careful observation and experiment, without leading to any clear view as to the real nature of the process, and affording but empirical rules for the minimising of the mischief. The evil is one of very long standing. Probably it was not very serious in the case of the old smooth bores, but when the introduction of rifling showed artillerists what an instrument of precision a gun might be at its best, attention was soon attracted to the rapidity with which this pristine accuracy was lost as erosion proceeded. Many costly experiments were made without, however, really elucidating the true character of the phenomenon. The purely laboratory work of metallurgists, made without any direct reference to the subject of gun erosion, seems, however, to clear up many points, and should bring us appreciably nearer a final solution of the problem.

In a paper read last February before the American Institute of Mining Engineers, Professor H. M. Howe showed that many points connected with the erosion of guns were rendered intelligible by a consideration of the iron-carbon diagram. For example, it has long been known that the interior surface of a gun became hardened on firing, the effect being perceptible even after as few as five shots. This hardening, though detectable at first merely near the chamber end of the rifling, spreads forward as further rounds are fired. The thickness of the hardened layer in an old gun may be as little as $\frac{1}{10,000}$ in. at the muzzle and 63 times as much at the breech end of the rifling. Professor Howe holds that this hardened layer is not due to carburisation of the metal, but is merely a result of heat treatment. As difficulties in the theory that carburisation is an effective cause, he notes that the products of combustion of modern propellants contain so large a proportion of carbon dioxide as almost to inhibit the carburising properties of the monoxide present.

Moreover, the time available for action of this kind appears to be far too short. Thus the liner of a 14-in. gun which was studied by Professor Howe had been worn out by the firing of 170 rounds. The total effective working life of this liner was accordingly only some 3.4 seconds, a time which is far too short, in Professor Howe's opinion, for any effective hardening to be produced by the carbon-monoxide of the gases, diluted as these are by a large percentage of CO_2. Professor Howe accepts accordingly the view that the hardening is the result of heat treatment, and that the hardened layer, as suggested some years ago by Rosenhain and Belaiew, is steel in the state of martensite.

In its normal condition the steel of the liner is a mixture of ferrite and cementite or α iron.* If this mixture be heated above a certain temperature the two constituents merge into each other, and if the combination thus produced be then quenched a hard alloy, consisting generally of needle-like crystals, is obtained. This is known as martensite. Professor Howe states that this is essentially what occurs to the inner face of a gun liner, but that owing to the peculiar conditions in which the transitions of the phases are effected, the needle-like crystallisation generally obtained is suppressed; but that the material is martensite nevertheless.

A peculiarity of the treatment to which the face of a gun liner is exposed is that the heating is extraordinarily rapid and lasts for an extraordinarily short time. The surface for a depth of many molecules is raised above the melting point of the metal and a wave of heat starts outward. Wherever the temperature wave rises to a sufficient height, the ferrite and cementite of the α iron begin to merge and form austenite. Hardly, however, has the wave started on its progress outward when the temperature at the face of the liner falls and the layer which has absorbed the original pulse of heat is then rapidly cooled by conduction outwards. The further away any layer lies from the face of the bore the lower is the maximum temperature attained, and this maximum at a very short distance from the face falls below the limit at which the transition into austenite is possible. Moreover, even when the requisite temperature is attained the time during which this temperature remains above the transition point becomes briefer and briefer the greater the distance from the inner wall of the liner. As time is required to change ferrite and cementite into austenite the amount thus transformed in any one heat wave becomes smaller and smaller the further the metal is from the surface of the liner.

After the projectile has left the gun, the thin layer in which austenite has been formed cools again, and this cooling is accompanied by some reversion towards the α condition. This reversion of phase takes more time to effect than the change from α iron into austenite, and some of the latter therefore remains untransformed and, being rapidly chilled, is converted into martensite. On a second discharge of the gun additional austenite is formed, and in this way the thickness of the hardened layer progressively increases. Its total thickness is, however, limited by the fact that as already pointed out the temperature necessary for the formation of austenite is only attained within a very thin layer adjacent to the inner surface of the gun.

The net result of the treatment above set forth is that the tough alpha metal which constituted the original face of the liner is replaced by a hard, but brittle, layer of martensite. The temperature gradient in this layer is extremely steep, and the transformed metal is too brittle to accommodate itself to the consequent differential expansions. Cracks form accordingly. On the lands of the rifling these are in the main transverse cracks, the reason being, Professor Howe states, that these lands are free to expand in a direction tangential to the bore. The straining action is thus less tangentially than axially in which direction the metal is firmly backed up by the solid metal of the body of the liner. In the grooves the principal cracks are longitudinal, since here the metal is not free to expand in the tangential direction.

Whilst the process above described accounts qualitatively for the character of the cracking the great extent of the mischief is due, Professor Howe holds, to a secondary cause. As the copper driving band of the projectile passes over the cracks these latter are stretched open and their hardened edges bite off mouthfuls of copper which are entrapped in the cracks and prevent these closing when the stress is released, and during the subsequent cooling of the metal. The result is that the crack is deepened or a fresh crack is formed. An examination of the worn-out liner already referred to showed the presence in the cracks of a relatively considerable quantity of copper.

Whilst the hardening, cracking and roughening of the bore can be accounted for on the above lines, something further is required to explain the actual loss of metal by which the bore is gradually enlarged. In Professor Howe's view this is due to the sweeping forward of the liquefied or plastic molecules at the surface of the liner by the rush of the powder gases A certain weight of metal is thus removed at each discharge.

With respect to remedies, Professor Howe expects but little from improvements in the metal used for the liners, though he suggests that possible benefit might accrue from the use of metal with a coarser structure than that now in favour. So far the resistance to erosion has been found to vary little over a wide range in the composition of the steel used. Some samples of gun steel cut from captured German guns show that the metal is of good quality, but contains no ingredients hitherto untried. One sample showed on analysis 0.372 C., 0.199 Si, 0.368 Mn, 0.017P, 0.025 S, 2.870 Ni, 1.270 Cr. In another sample the proportions were 0.430 C, 0.229 Si, 0.218 Mn, 0.016 P, 0.045 S, 2.670 Ni, 0.136 Cu, 1.350 Cr, 0.040 Co. There is nothing here we may note to justify the claims made by Krupp in years past to having found a non-erodible metal. That the claim was only a bluff was proved before the war by the refusal of the firm to take a very large order for armaments on the basis that these claims should be justified. In this case when it came to actual business Krupp was not prepared to guarantee any longer life to his guns than his competitors were.

As a practical remedy for erosion troubles, Professor Howe pins his faith to the system of relining first adopted we believe by this country, an example which was followed later by the United States. Mr. Hudson Maxim, on the discussion of Professor Howe's paper, said that it took three weeks and cost 17,286 dollars to reline a 14-in. gun. Since, however, a considerable reserve of guns was maintained in store it was not necessary to hold up a ship whilst new liners were being fitted. He further stated that as the result of recent experiments the Navy Board had made great progress in overcoming erosion troubles. Over 250 rounds had been fired from a 14-in. gun, and it was still accurate.

Other contributors to the discussion said that where smaller bores were concerned careful oiling increased the life of the weapon by some 85 per cent. Graphite blown in was said to be almost useless, but sperm oil carefully rubbed in had been found very effective. For weapons of rifle calibre the provision of a wad of cardboard at the base of the bullet was said by Mr. C. I. B. Henning, of the Du Pont Powder Company, to greatly reduce the erosion from cordite, and good results had, he said, followed the adoption of the same plan for field pieces.

* See "The Iron-Carbon Equilibrium Diagram and its Practical Usefulness," ENGINEERING, April 12, 1918, page 394.

GERMAN STATE RAILWAYS DURING THE WAR.

The German railways have done exceedingly well during the war as regards receipts. The following table shows the receipts for the years 1913–16, from which it will appear that although the receipts for 1914 fell short of those of 1913, the latter were already exceeded by the receipts for 1915, as shown by the table in the next column. The figures for 1917 are not yet fully available, but up to the end of September, 1917, the receipts for the first nine months of that year exceeded those for the corresponding period of 1916 by 30 per cent. on the passenger traffic and 5 per cent. on the goods traffic. Compared with 1913 the following year showed an aggregate decrease of 282,000,000 marks, 1915 shows an increase of 11,000,000 marks and 1916 an increase of 462,000,000 marks.

Large sums have been expended on improvements of the lines and on increase of the rolling stock, so

that the latter, at the end of 1917, had increased its value some 30 per cent. compared with 1913. In spite of the substantial increase in the receipts the war cannot be said to have improved the financial position of the railways, as the increased expenditure more than counterbalances the increased revenue. With the present level of wages and prices the increased expenditure for the current year, as compared with that for 1913, will account for some 1,100,000,000 marks. The balance would have been further reduced had not the passenger service been very materially curtailed. An involuntary saving has arisen from the limitation to repair work as regards the permanent way, locomotives, &c., from shortage of raw materials and labour. This, of course, means increased expenditure at some future period.

1913.	1914.	1915.	1916.
	Passenger Traffic.		
marks 713,000,000	marks 587,000,000	marks 570,000,000	marks 798,000,000
	Goods Traffic.		
1,671,000,000	1,508,000,000	1,754,000,000	1,925,000,000
	Aggregate Receipts from all Sources.		
2,557,000,000	2,275,000,000	2,568,000,000	3,019,000,000

According to official statistics the German State railways, under the joint Prussian-Hessian management, comprised, on March 31, 1917, 39,943 km. ordinary gauge; of these 38,594 km. were Prussian, 1,307 km. were Hessian, and 41 km. were Baden. Of the above, 22,685 km. were worked as main railways and 17,257 km. were worked as branch lines. Of the former 5,398 km. had one set of rails, 16,830 km. had two sets of rails, 84 km. had three sets of rails, 365 km. had four sets of rails, and 5 had five sets of rails. Of the branch lines, 16,642 km. had 1 set of lines and 615 km. had two sets of lines.

Further, there were 239 km. narrow-gauge railways—all Prussian. There were consequently open to general traffic 40,182 km. In addition there were connected railways not open to general traffic, 202 km., almost exclusively Prussian.

The capital invested, on March 31, 1917, amounted to 13,455,584,735 marks on Prussian ordinary-gauge lines, 389,749,100 marks on Hessian ordinary-gauge lines, 13,320,119 marks on Baden's ordinary-gauge lines, 20,390,775 marks on Prussian narrow-gauge lines, and 12,342,368 marks on connecting lines. The cost of the normal-gauge railways comes out at 348,639 marks per kilometre for Prussian lines, 305,008 marks per kilometre for Hessian lines, and 323,933 marks per kilometre for Baden lines. The cost of the narrow-gauge railways amounts to 85,281 marks per kilometre.

On the above lines the traffic during the year of 1916, including foreign rolling-stock, amounted to 25,079,616,565 axle-kilometres, of which 6,276,951,411 referred to passenger stock and 17,161,013,560 referred to goods stock. Upon the capital invested an interest of 6·24 per cent. was earned in 1916, against 5·58 per cent. in 1915. The surplus amounted, in 1916, to 28·32 per cent. of the aggregate receipts, against 28·87 per cent. in 1915.

The Prussian surplus from the ordinary receipts, with the deferred expenditure deducted, amounted to 822,100,000 marks, which was applied as under: 358,500,000 marks to interest on railway loans, 51,100,000 marks to statutory reduction loans, 144,000,000 marks towards extraordinary expenditure (making a total of 554,200,000 marks for railway purposes), 1,400,000 marks were applied to a special fund, leaving 266,500,000 marks available for other State purposes.

Apart from increased tariffs, other reforms have been introduced or are under contemplation. Thus the so-called D trains will be reduced to two classes. Two-thirds of the trains are to consist of second and third class, and one-third of first and second class. The latter are intended for the great international traffic and for connection between centres of special importance, and by reducing the number of places where these trains are to stop, the speed will be increased. In the ordinary passenger trains first class will be abolished.

The war has also, in other respects, wrought great changes in the railway service, and the railway Minister stated on a recent occasion, that 107,000 women had been engaged in railway work and had done surprisingly well. The crowding of the trains was also a result of the exceptional conditions, thus 65,000 workmen now had to be conveyed to Spandau (State weapon factories), against 25,000 in peace times. It was also stated that the combinations of the railway workmen were demanding more wages; the wages of the men had almost been doubled within a year, and the expenditure for increased pay amounted to 551,000,000 marks in 1917, as compared with 1916, and the pay of the workmen had been raised far more than that of the railway servants. Mention has also been made of the large increase of theft on the railways, as almost everywhere else, in Berlin at least, and this was no doubt to some extent attributable to insufficient pay and to scarcity of food.

On April 1, an alteration took place in the calculation of the fares which seems to cause a good deal of disappointment. It was expected that the former ticket tax would be abolished and in its place an additional charge of 10 per cent. introduced and a further addition of 10 per cent. to 16 per cent. imperial traffic-tax, an arrangement which would affect particularly the fourth class, which had hitherto been free from ticket-tax. This, however, does not apply to the express trains, inasmuch as one class is to cost as much as the price for two passenger train tickets, the first class, for instance, to cost as much as the second and third class together. The price will only be a little lower than the present exceptional charge, and the railway department seems determined to maintain a pronounced difference between the prices for passenger and express trains.

ELECTRIC POWER SUPPLY.

THE Committee on Electric Power Supply appointed by the Board of Trade early in 1917 has just issued its report. The task set was to state the steps necessary to secure an adequate and economical supply of electric power for all classes of consumers and particularly for industries requiring a cheap supply. The report outlines a new scheme of administration, but contains no figures or estimates as to the cost of carrying out the proposed change or the reduction, if any, in the price of current that would be likely to result. The advantages of a cheap and plentiful electric supply are strongly and repeatedly urged all through the report—an advantage which no one disputes. No facts or figures are given in the report to indicate the extent of the inefficiency of the present system or the loss or waste resulting from it. It is admitted that the electrical industry has met the sudden and extensive demand for expansion occasioned by the war. Also that many manufacturers prefer to generate current for themselves—this right is reserved to them. The new administrative scheme provides that five national commissioners, acting as a central authority, should control the supply works for the United Kingdom, taking over the powers now exercised by the Board of Trade, the Local Government and the equivalent Scottish and Irish authorities. This central authority would divide the country into about 16 districts, in each of which a District Board would be established to work the local supply, subject to the sanction and inspection of the central authority. The constitution of the Boards may be various: (*a*) Nationally financed and consisting of representatives of local authority and company distributors, large consumers and railway companies; (*b*) locally-financed and consisting of representatives of local authorities, distributor companies, large consumers and railway companies; and (*c*) mixed Boards of similar interests in proportion to finance contributed locally and nationally. The authorities and companies would each nominate an "electoral body" which would select the Board members by ballot vote. For the local consumers' election, every consumer would have a vote for each 200*l.* worth of current consumed, the smaller consumers being without votes. No national representatives are proposed. The District Board would acquire all the generating stations, "good and bad," on the same general terms, viz., payment of actual expenditure on lands, buildings and plant less amount of depreciation, reserve, &c., funds, and would have power to take railway, tramway, dock, &c., generating plants on the same terms. The taking over of distribution systems is more or less optional on both parties, subject to certain limitations of control if the distribution is carried on as hitherto. The national capital is to be raised by the issue of Government Electricity Stock. Local authority systems would be paid for by terminable annuities corresponding with their obligations and private-owned systems would be paid for in cash. Having acquired the systems the Board would either work them directly or lease them to commercial companies—preferably to those from whom they have been purchased. The capital hitherto expended on all public supplies is stated as 36,000,000*l.* by 230 companies and 55,000,000*l.* by 327 local authorities—total, 91,000,000*l.* These figures are given as "an approximate estimate." No authority for them is quoted and, presumably, a proportion of the 55,000,000*l.* has been repaid, but this point is not dealt with. The amounts cover distributive as well as generative systems. The object is to remodel the generative systems, concentrating them into large power plants and scrapping much of the small and out-of-date machinery. This work is to be pushed forward immediately after the war, notwithstanding the high prices that are expected to prevail, but no estimate of the cost is given. The difficulties of cost of wayleaves, local rates, opening streets and roads, &c., are mentioned, but left to the Government to deal with. Immediate legislation is recommended.

GYPSUM PRODUCTS.

THE use of gypsum is as ancient as it is simple, possibly ancient because simple. The mortar of the Great Pyramid consisted very largely of gypsum; dried corpses were painted with gypsum and pigments; plaster casts were taken by Greek artists; large tabular crystals of gypsum served as windows in Spain, and rock gypsum and plaster were utilised as building materials by the Romans, long before Italian artists specialised in stucco work and the modern builder made gypsum concrete. Gypsum is calcium sulphate, $CaSO_4$, occurring in nature without water as anhydride—unfortunately spelt anhydrite—and as the hydrate $CaSO_4$, $2H_2O$, the gypsum proper, which loses most of its water at 110 deg. C., passing into $CaSO_4$, $0{\cdot}5\ H_2O$ (sometimes found in needle crystals in boiler incrustations); the latter reabsorbs water and hardens into a material of great durability. The sulphate, which forms when lime is neutralised with sulphuric acid, is the ordinary gypsum; it is a nuisance to the laboratory chemist who frequently discovers that the fine crystals he has obtained, after laborious operations, are nothing but gypsum, and a still greater nuisance when the neutralisation has to be carried out on a big scale. For gypsum is plentiful, the sulphate so gained has little value, and all attempts to recover the sulphuric acid from it have so far failed. Gypsum, one may say, in fact, has little chemistry. Many books on industrial chemistry do not treat of gypsum at all. But it has an important technology, and the most recent monography [67 pages] on "Gypsum Products, their Preparation and Uses," which Mr. R. W. Stone, of the United States Geological Survey, has compiled on behalf of the Bureau of Mines (Technical Paper 155), forms a valuable addition to this literature.

The weight of gypsum mined in the United States, either as gypsum rock or as earth (gypsite), has steadily risen from 70,000 short tons in 1880 to 2,599,505 tons in 1913, decreasing somewhat to 2,477,611 tons in 1915; the imports from New Brunswick and Nova Scotia, never more than one-third of the production, have almost vanished. In 1915, 68 mills were engaged in the gypsum industry, 20,000,000 dols. were invested in it, the calcined plaster manufactured was valued at 5,946,000 dols., and the value of all gypsum products was estimated at 7,000,000 dols. The ways of utilising gypsum are extending. Sculptors make use of the fine-grained semi-translucent variety, known as alabaster; block gypsum as such serves in the arid States as building material for houses and also for making roads. Ground gypsum has more uses. Before

a gypsum industry proper developed, ground gypsum, so called land plaster, was spread on the ground as a fertiliser; that is still done; ground gypsum is also used as a flux in lead and copper smelting and as a filler in cotton cloth; it is mixed with pigments and paints, or added as adulterant to flour and sugar; it helps to give paper a glossy finish, forms the base of ordinary blackboard chalk (crayons), and some 400,000 tons of gypsum (raw or calcined) are added to Portland cement to retard its setting; it has also replaced limestone in cement.

All these uses are, however, by far outweighed in importance by the manufacture from gypsum of plaster, even in the United States, though the first plaster mill of New York State only dates from 1892. For this manufacture the gypsum is first crushed, dried in rotating cylinders and ground. One machine for pulverising soft rock, now much in favour in American gypsum mills, is a disintegrator comprising four cages of bars, moving two in one direction and two in the other. The material is fed into the centre, and has to escape through the bars when broken sufficiently small. The machines, built up to 50 in. diameter for a capacity of 75 tons in 10 hours, require up to 45 h.p.

As the calcium sulphate loses its water at 110 deg. C., and as the gypsum must not be dead-burnt, only moderate temperatures are required, but the operations are carried on with such big bulks that higher temperatures are commonly used. At the temperature mentioned (230 deg. F.), the ground mass begins to boil vigorously; as the temperature is raised to 270 deg. F. (133 deg. C.), the boiling quiets down, and the mass, having lost about 14 per cent. of its volume, consists after this "first settle" mainly of $CaSO_4$, $\frac{1}{2}$ H_2O. On further heating, the gypsum boils once more till the "second settle," when 18 per cent. or 20 per cent. of the volume will have been lost, and the gypsum will all be the semi-hydrate, together with a small percentage of the anhydride. As a rule the calcination is interrupted after the first settle between 310 deg. and 350 deg. F.; for bedding glass plates and producing a very dense strong casting the calcination is continued to the second settle. The calcination is effected in kettles and, to a small extent, in kilns. The kettles for "boiling or cooking" the gypsum are cylinders made of $\frac{3}{8}$-in. boiler plate, with much stronger convex bottoms, up to 14 ft. diameter, 10 ft. deep, and of 10 tons weight, taking 20 tons of gypsum, and requiring up to 25 h.p. for stirring; the calcination lasts an hour or two. In the continuous rotary kiln or Cummer process, used in three mills, a rotating cylinder, 5 ft. diameter, 30 ft. long, is slowly turned about its nearly horizontal axis; the hot furnace gases enter the cylinder through a series of hooded traps, which are arranged in a spiral round the shell and resemble the outlets of ventilators on board ship. The calcination in the cylinder, which is provided with internal shelves and lifting blades, at 400 deg. or even 600 deg. F. (200 deg. to 315 deg. C.) takes about 10 minutes, and the still-steaming mass is discharged into a system of bins (not heated) in which the dehydration is completed; as these bins have to be stirred, the new Cummer cylinders are made 70 ft. long like cement kilns, to complete the calcination in one operation. Stationary kilns, resembling beehive coke ovens, are used in a few works, and the gypsum sand is, at Almogordo, in New Mexico, calcined in a baffle plate furnace provided with adjustable sloping shelves, down which the mass slides. When kilns are used, the gypsum needs only to be crushed, not pulverised as for the kettles.

After the calcination follow screening, regrinding and mixing with various materials. Retarders (glue, hair) are added when the plaster is not to set too quickly, accelerators serve for the opposite purpose, *e.g.*, in dental work to reduce the time of setting from 6 minutes to 3 minutes; this is done with the aid of alum or simply of continually stirred, well-dried and reground plaster. The retarders also act as fillers and give strength. Such are hair (cattle or goat hair, 3 lb. to 5 lb. per ton of plaster) for wall plaster; sisal or manila fibre or wood (cotton wood, bass wood), 20 lb. to 50 lb. per ton), dried sand, hydrated lime, &c. The point is to supply a plaster which needs only to be mixed with water to be ready for use. Hair and wood fibre plasters are light and non-combustible. Plaster board, sheets of plaster (consisting of several layers of felt, paper, or wood and gypsum) are only made in a few works by slow (short) or fast-running (long) machines of the conveyor type, the latter up to 800 ft. long. Gypsum tiles, hollow or perforated, for partitions, floors, domes, &c., are completely made by one machine. Moulded building blocks of plaster are popular for garages, &c., in the arid districts of Arizona, Wyoming, &c. The slow-setting but finally very hard Keene's cement is also manufactured in the United States. Either the gypsum is partly dehydrated to 2 $CaSO_4$, H_2O, soaked with alum or borax, and then recalcined at 500 deg. C., or it is calcined in a kind of small vertical lime kiln at red heat, treated with a 10 per cent. solution of alum, dried, and again calcined for 6 hours or 8 hours; the actual processes are secret, however. Borax alone is said to answer as well as when mixed with alum or cream of tartar. The chemical reactions are not well understood, and the recent discussion of the Setting of Cements and Plaster by the Faraday Society* left many questions unanswered.

JAPANESE TRADE.

We have received from the Department of Finance, Tokyo, a copy of the seventeenth financial and economic annual of Japan, which contains a large amount of interesting information.

From this we see that the extent of the coast of Japan, including Korea, Formosa, the Pescadores and Japanese Saghalien, is 18,115 miles, the total area being 258,575 square miles. The total population of Japan proper in 1916 was 55,965,292, that of Korea 16,913,224, that of Formosa 3,710,848, and that of Japanese Saghalien 95,194. In 1907 the population of Japanese Saghalien was only 20,469.

The general budget for the financial year 1916–17 estimated the revenue at 61,552,637*l.* and the expenditure at 61,688,310*l.*, leaving a balance of 135,673*l.* on the expenditure side; but as some items of ordinary expenditure, owing to the war, were transferred to extraordinary military expenditure, and since a sum equal in amount to the latter figure had been left unused, the revenue and expenditure accounts have balanced. A table in the report, giving the annual State revenue and expenditure starting from the financial year 1876–77 shows a surplus of revenue in every year, except for the year 1883–84, when both were balanced. In the financial year 1876–77 the revenue amounted in round figures to 5,981,000*l.* and the expenditure to 5,930,000*l.*

In the estimated revenue for 1916–17, the ordinary taxes entered for 54,450,000*l.* and the extraordinary taxes for 7,102,637*l.*, making the above total of 61,552,637*l.* In the ordinary revenue the receipts from public undertakings and State property entered for about 17,634,700*l.*, then followed the tax on liquor, for 8,987,500*l.*; the land tax, for 7,281,600*l.*; the postal, telegraph and telephone services, for 7,023,000*l.*; the tobacco tax, for 5,906,200*l.*; and the income-tax, for 3,688,100*l.* Customs duties were estimated to yield 3,165,400*l.*

The land tax is levied according to the value of the land, which is assessed on the basis of capitalising the net rent of the land, and is entered in the register of the survey of lands. The report states that this tax is collected from the "pledgee" in the case of land under pledge, from the "superficiary" in the case of land under superficies, or lease, of more than a hundred years' duration, and in all other cases from the landowner. The income-tax is collected from A, those persons who are domiciled or have resided for at least one year in places within the Empire; B, those persons who, though not domiciled nor residing within the Empire, have property, or are engaged in trade or business, or receive interest from public bonds or companies' debentures in places where the income-tax law is in force. They are, however, liable to pay the tax in respect only of the income derived from such sources. The rates are as follow: Class I.—A, ordinary partnerships and limited partnerships, 4 per cent. to 13 per cent.; B, joint-stock companies, joint-stock limited partnerships and other "juridical" persons, 6.25 per cent. Class II.—Interest on public loan bonds or companies' debentures, 2 per cent. Class III.—Incomes not included in the preceding two classes, 2.5 per cent. to 22 per cent. The following two provisions are the most deserving of notice for the calculation of assessable incomes: (1) In the case of salaries and allowances among the incomes of the third class, the estimated annual income is reduced by 10 per cent. for the assessable value; (2) the calculated amount of the income of the third class is for the purpose of assessment reduced by 15*l.* if it is not more than 50*l.*, by 10*l.* if it is not more than 70*l.*, and by 5*l.* if not more than 100*l.* In Japan, the State has the monopoly of tobacco, salt and camphor production, by far the most important of which as a source of revenue is that of tobacco. Under the Imperial Railways' Special Account Law, revised by Law No. 6 of 1909, the receipts and expenditure of the Imperial Railways are set apart and are independent of the general account. The last time the railway receipts were included in the State revenue account was in the case of the financial year 1908–09, when the sum was 3,511,400*l.*

The report gives in detail and for a period of ten years the areas in cultivation and the total agricultural production, then follow data on the industry and commerce of the Japanese Empire. The employees in metalliferous mines on June 30, 1915, numbered 86,359, those in coal mines numbered 193,142, and those in non-metalliferous mines 10,583, equal in total to 290,084, who worked a total of 69,943,202 days. The coal output in the same year amounted to 20,400,747 metric tons, valued at 6,507,000*l.* The coal consumption was 4,575,961 metric tons in Japanese ships, 809,254 metric tons in foreign ships, 1,915,767 metric tons for railways, 8,132,728 metric tons for factories, and 826,268 metric tons for salt manufacture, equal to 16,259,978 metric tons. The coal exports amounted to 2,900,885 metric tons, and the coal imports to 609,799 metric tons, for the same year, 1915.

The factories worked by motors numbered, in 1915, 10,688; those using steam engines had available a total of 265,934 h.p., those using steam turbines a total of 215,151 h.p., followed by gas for 43,101 h.p. and petroleum for 4,696 h.p. The water-turbine factories had available 230,715 h.p., and those which derived their power from Pelton wheels had 84,241 h.p. The electrically-driven factories had a total of 221,886 h.p. The factories not worked by motors numbered 6,121, making a total of 16,809 factories, which in 1915 gave employment to 350,976 males, and 559,823 females, equal to a total of 910,799. The electric supply companies numbered 485 in 1915, as against 103 in 1906; and the gas supply companies 87 in 1914, as against 7 in 1905.

The total value of exports amounted in 1916 to 112,746,800*l.*, and the total value of imports to 75,642,800*l.*, the excess of exports over imports being therefore 37,104,000*l.* These figures do not include those for the foreign trade of Korea and Formosa. The exports to Asia amounted to 50,548,700*l.*, those to Europe to 21,644,900*l.*, of which Great Britain took 10,265,800*l.* in value and France 6,400,700*l.* The value of the exports to the United States of America amounted to 34,024,500*l.* In the same year, the Japan imports from Asia amounted to 36,829,000*l.*; from Europe 10,844,200*l.*, in which total Great Britain entered for 8,173,200*l.* Japan imported from the United States goods to a value of 20,407,900*l.*

The report from which we quote also gives interesting figures on the Japanese Railways. From these we see that the mileage of the State systems open to traffic amounted at the end of the year 1915–16 to 5,757 miles, whilst the privately-owned systems had a developed length of 1,743 miles, a total of 7,500 miles. The State-owned locomotives numbered 2,679 and the privately-owned numbered 428, a total of 3,107. The average fare per passenger was 0.290 yen (7.129*d.*) on the State railways and 0.122 yen (3*d.*) on the private railways, whilst the average fare per passenger-

* See ENGINEERING, January 18, 1918, page 71, and February 1, page 109.

mile was 1.32 sen (0.325*d.*)on the State railways and 1.73 sen (0.425*d.*) on the private railways. For goods traffic, the average freight per ton was 1.580 yen (38.840*d.*) on the State railways and 0.461 yen (11.332*d.*) on the private railways; the average freight per ton-mile was 1.71 sen (0.421*d.*) and 3.53 sen (0.868*d.*) respectively.

The principal mineral products of Korea are gold, silver, zinc, copper, lead, iron, graphite, coal, and tungsten ore; the country is especially rich in gold, iron, graphite and anthracite. Gold-mining on a large scale had hitherto been carried out mainly by Europeans and Americans, but large mine-owners in Japan have of late commenced mining in various parts of the peninsula. The foreign trade of Korea in 1916 amounted to 13,444,509*l.*, of which 5,818,082*l.* was the value of exports and 7,626,427*l.* that of imports. The exports were mostly grain and seeds; ores, metals and metal goods. The imports, on the other hand, covered mostly cotton tissues.

Formosa is rich in agricultural produce, whilst the most important mineral products are gold, silver, alluvial gold, copper, coal, petroleum, sulphur and phosphorus, most of which come from the northern part of the island. According to the investigation in regard to mining in Japanese Saghalien made since 1905, the principal mining product is coal, next to which come alluvial gold, petroleum and iron pyrites. There are three important coalfields in the island, the greatest of which is the middle coalfield, which extends over 60 miles, the width varying from 1 to 3 miles.

NOTES.

The Photographic Spectra of Aerolites.

Distinguishing the meteorites, the cosmic wanderers which are drawn down upon our earth, as siderites when they consist essentially of iron and nickel, and as aerolites when they are essentially silicates of the olivine type interspersed with nickliferrous iron, Sir William Crookes recently submitted some aerolites to spectroscopic examination. The paper, which he presented to the Royal Society deals only with the spectroscopic analysis of thirty aerolites, mostly samples of 2 or 3 grammes weight obtained from the Natural History Museum. General analyses of these aerolites are not given. For the spectroscopical tests, use was made of a spectrograph which Sir William reconstructed at least six times. Sir William photographed the spectra of the aerolites and compared these photographs as to line intensity and position with the photographs of the spectra of similar compounds and specially prepared mixtures. For this purpose he needed a slit of constant width for experimenting on different days; his usual slit width being only 0.008 mm., he found considerable difficulty both with the slit material and the mounting. Schumann, in studying his rays in the ultra-violet, had used jaws of hardened steel; Crookes wished to study the whole spectrum, and his chemical laboratory was inconveniently near his physical laboratory for making use of iron jaws. Having tried rolled, non-corrosive cobalt, he finally adopted quartz jaws; but the sharp edges of 45 deg. splintered too easily, until he put a very narrow bevel on the front of the quartz plate, so that the sharp edge formed an angle of 90 deg. To prevent stray light from passing through the plate, he covered the quartz with gold, by kathode deposition up to the edge. In order to secure constancy of the slit width, he mounted three jaws, of widths 0.008, 0.025, 0.06 mm., on blocks of pairs of "fixed slits" of brass. As regards the gases in the meteorites, about which there is considerable controversy, Sir William merely describes the arrangement he made to convince himself of the absence of inert gases, notably of helium; he absorbed the gases escaping from the aerolites at red glow, after Soddy, by heating them with metallic calcium, which would bind all but the inert (rare) gases. The spectroscopic examination shows that only eleven elements occurred in the aerolites; iron, chromium, nickel, magnesium, silicon, sodium, manganese, and also potassium, aluminium, calcium. The first four were alone present in quantity and, with three exceptions, always in the nearly same proportions. That, Sir William writes, seems to suggest that the different aerolites had a common origin in the disruption of some stellar body which had completed its cosmical evolution, in other words, that the aerolites were fragments of a finished cooled planet. The siderites would have a different origin, or might have formed the solid core from which the chromium and other elements would have separated, leaving the magnetic elements iron and nickel as a residue in the familiar meteorites. So far as we are aware, the aerolites generally found are supposed to differ from terrestrial rocks, resembling the periodotites most, aqueous silicates of magnesium, calcium, iron and aluminium, which are characterised by the presence of small percentages of chromium and nickel.

Volcanic Investigation of Kilauea.

The systematic volcanic observations which have for many years been conducted on Mt. Vesuvius and Ætna have of late been excelled by the observations on the Island of Hawaii (Sandwich Islands). The whole island, which is of more than half the area of Wales, is volcanic; the peaks, the Mauna Kea and the Mauna Loa (white and great mountains), the highest in the Pacific, rise to nearly 14,000 ft., and craters several miles in diameter can be seen. The most interesting of the volcanoes is the Kilauea, about as high as Vesuvius, but distinguished by a crater with vertical walls, nearly 1,000 ft. across, part of which is generally taken up by the Halemaumau, a lake of boiling lava. The first reports of nearly a hundred years ago spoke of a lake at a depth of 1,000 ft. in a crater 4,400 ft. wide. Within the last decade accounts of many varied observations have been published, chiefly in the *American Journal of Science*, and in 1912 an observatory was established on Kilauea by Professor T. A. Jaggar, a geologist of the Massachusetts Institute of Technology. The chief American observers, Daly, Day and Shepherd, and, further, A. Brun, of Geneva, and J. A. Perret, of Naples, are not in agreement as to their conclusions, but certain observations seem to be incompatible with long-favoured opinions. Since most volcanoes are situated near the sea shore, water has been supposed to play an important part in volcanic activity, though infiltration of sea water was not generally believed in. Brun questioned the water influence altogether, and the many analyses of gas bubbles from the lake and exhalations support him. The gas from a flaming cone in the floor gave the following percentages: Water vapour, 4; SO_2, 50; CO_2, 25; CO, 2; H, 3; S, 3; N, 14. Thus 79 per cent. of the gases were combustion products, and only 7 per cent. combustible. Jaggar argues that air is constantly introduced into the lake by the avalanches of crags falling into the lake, and more is drawn in through the porous rock and down the chimneys, and that this air oxidises the constituents of the magma and heats and fuses it. The whole phenomena resemble those of intermittent hot springs. The lava rushes up certain rather narrow shafts, and sinks down in others; distinct streams can often be seen. Though the lake depression (under the outer rim of its crater) fluctuates by hundreds of feet, the lake, it is found, is always shallow; depths of about 50 ft. were measured with the aid of long steel tubes lowered into the lake, and temperatures probably of 1,350 deg. C. estimated (partly by Seger cones), but not of 3,700 deg., as suggested by Daly for very deep lakes. Jaggar distinguishes between a semi-incandescent, viscous beach magma, and a liquid lake magma, the latter being the product of chemical reactions with the air at greater depth and passing into the former. When the lake level is depressed, its semi-fluid saucer (bottom) and the islands sink with the level. The islands do not float, though they change vertically and horizontally. When a big crag caves in on one side of the lake, an island may rise on the other side. On June 5, 1916, simultaneously with the conclusion of a great lava flow from Mauna Loa (16 miles distant), the level of the lava lake sunk 400 ft. in two days, the lake having all the time the appearance of a shallow steaming puddle. There is certainly no evidence of a lava lake hundreds of feet deep; rocks tumbling into the lake always seem immediately to strike the bottom. The viscosity of lava has received increasing attention since the eruption of Mount Pelée in 1902, and we agree with Professor Jaggar on many points, particularly that systematic observations, and not volcanic expeditions, will solve the problems. When he suggests, however, that selenologists may help, since the crags of beach magma resemble the steep peaks rising from the floor of lunar craters, we fear that he fails to bear in mind the enormous difference in scales.

Natural Gas used for Lighting at Pisa.

Some years ago at a farmhouse of Agnano, at a distance of less than two miles from Pisa, a boring was made, says Professor Luiggi, with the object of raising water for domestic and agricultural purposes. No water was struck, and a gas jet burst forth from the borehole. The gas was found to be combustible and it has been used since to supply gas lamps in the locality and district. Owing to the present scarcity of coal, the price of which has risen to fantastic heights, this modest attempt of lighting a township with natural gas attracted the attention of a well-known chemist of Pisa, Dr. Sivieri, Director of the Piombino Smelting Works, who was anxious to ascertain whether there existed in the locality a source of natural gas similar to those met with in petroleum bearing districts, small counterparts of which are found in the Pistoia Appenines, at Salsomaggiore, Sassuolo, Tocco di Casauria and other places in Italy. With that end in view, Dr. Sivieri had more borings made, using steel tubes 3 in. in diameter, which were driven down to a depth of 130 ft. to 250 ft. The surface consisted of a layer of vegetable mould, and below that, to a depth of 98 ft., fine, compact clay was encountered, below which was a 3 ft. stratum of peat, followed by peaty sand and pure sand, down to the depth of 250 ft. The tubes had scarcely reached the peat stratum when abundant gas jets issued forth, which on analysis revealed the following components:—

	Per Cent.
Methane or marsh gas	85
Hydrocarbons	2
Nitrogen, carbonic acid and other gases...	13

In the ordinary burners, this gas gives a weak flame, but when using a gas mantle, a most brilliant light is obtained; its calorific value is 9,000 calories per cubic metre (1,000 B.T.U. per cubic ft.), or about double that of ordinary lighting gas. The gas issues from the bore tubes at a pressure of 1 atmosphere to 1.5 atmosphere, and by connecting together the various borings, the supply was found to reach a total of several thousand cubic metres per day. The tubes have since been connected by a suitable main to the Pisa gasholder, where the natural gas pressure is reduced to the ordinary pressure, and whence it is distributed for lighting and heating throughout the town of Pisa. Six tubes are thus connected up and are sufficient for the present needs, but work is in progress for adding 12 more tubes, which have been sunk at different parts of the locality. The district from which the natural gas is tapped has an area of about 5 sq. km. (about 2 sq. miles). This natural gas, which has, as stated above, approximately double the calorific value of coal gas, can be sold for less than a third the present price of the latter; this means a large saving both for the inhabitants of Pisa and for the national treasury. The question naturally arises as to how long the natural supply will last. Judging from the experience at the Agnano farmhouse, and considering the very high pressure at which the gas issues from the bore tubes and also the wide extension of the peat stratum from which the gas originates, the supply can be expected to continue for several years, when it will exhaust itself as in the case of similar tappings in Pennsylvania. In any case, there is an abundant supply for the present, more than is sufficient for Pisa and the neighbouring townships, and it is proving of great advantage.

Motor-Car Fuel Control.—The "Berdea" is an attachment for Ford motor cars and vehicles which automatically acts on the adjustable needle of the carburettor to give a richer mixture at low speeds and a poorer at high speeds. It may be called an invention called into existence by the increased cost of fuel, and it is claimed that the effects on the engine and gear-box will be beneficial in addition to the advantage of fuel economy. The sole agents are Messrs. Brown Brothers, Limited, Great Eastern-street, E.C. 2.

LITERATURE.

An Inquiry into the Analytical Mechanism of the Internal Ear. By SIR THOMAS WRIGHTSON, Bart., with an Appendix on the Anatomy of the parts concerned by ARTHUR KEITH, M.D., F.R.S. London: Macmillan & Co., Limited, St. Martin's-street. [Price 12s. 6d. net.]

FOR many years Sir Thomas Wrightson has occupied himself with the problem of tracing the operations of the mechanism by which sound waves, carried by the atmosphere, can be converted into brain messages. In this volume he gives the result of the enquiries and experiments, suggested by his engineering training, into the effects of pressures and displacement on the several parts of a complicated machine, that in some way transmits the sound waves from the ear to the nerve terminations. Further, there is evidence not only of transmission, but also of a power of analysis of compound waves. Apparently there is an apparatus within the ear, capable of resolving a compound wave into its original simple constituents, as effectively as the application of algebraical analysis enables us to represent a complex curve by a series of harmonics. As an accomplished musician, the author's attention was first directed to detecting the mechanical process by which this analysis is effected, and some years ago he submitted a theory which was received with respectful attention. This theory is now again offered, strengthened by the additional evidence drawn from the most recent anatomical researches. The generally accepted explanation is due to Helmholtz, who suggested the application of the principle of resonance to the tightly stretched elastic fibres of the basilar membrane. The author's early researches led him to distrust the adequacy of this explanation, and he declined to join in the chorus of assent with which physicists and anatomists hailed this suggestion as an acceptable working hypothesis. This attitude of cautious reserve is apparently justified, for anatomists are no longer unanimous in regarding the theory as sufficient. Dr. Keith complains that recent text-books treat the internal ear as if it were a piece of architecture and not a machine. The author emphasises the difficulty of applying the theory of resonators to a membrane vibrating in a fluid, and other writers have shown that the basilar fibres are not free strings but are embedded in a cementing substance, while in consequence of the gradual extending knowledge of the minute structure of the cochlea, other effects have been brought to light equally difficult to reconcile with the theory of resonance. The direction of modern criticism is well summarised by Dr. Keith.

It must be remembered that whatever views are held concerning Helmholtz's system of resonators, and however satisfactory this explanation of a large series of phenomena may appear, there is still a mechanical problem to be solved. Known physical forces are operating on a complicated system of levers and appliances, and the method of working deserves to be traced. Helmholtz treated the problem mainly as a physicist: the author approaches it as an engineer. Helmholtz was convinced that the only means by which the ear could carry out its analytical functions was by a system of resonators, and he concluded that the ear having the power must necessarily possess such a system. The anatomical side did not much interest him; in the strength of his convictions he believed that later researches or discoveries could only harmonise and support his hypothesis. Sir Thomas saw from the first that progress, divorced from conjecture, could be made only with the assistance of an expert anatomist, for conscious that he had to deal with an intricate machine, he wanted to set up a working model in order to trace effectively the manner in which known forces would work on this mechanism, and to satisfy himself that every part was fulfilling its appropriate function. The criterion of a rational theory of the auditory apparatus consists in its capacity to provide a complete and convincing explanation of the co-ordination and fitness of the several parts to secure definite ends. Fortunately, Sir Thomas found the necessary assistance in Dr. Arthur Keith and the two have loyally co-operated in the common task. We may congratulate ourselves on this alliance, for it has resulted in Dr. Keith contributing to this volume a valuable appendix, in which he not only follows step by step the growth of our knowledge of the minutest detail of the internal ear, but enables us to see the many parts assembled, and the whole pictured as a working unit.

It is a question whether the reader's interest would not be increased and the work made more informative, if the appendix were read before the treatise. The decision will probably depend on the amount and character of the previous knowledge the reader brings to bear upon the subject. Few are equally familiar with the action of the steam engine indicator, whose working guided Sir Thomas in his early researches, and the movement of the organ of Corti or the behaviour of the basilar membrane. The present writer is certainly not one of the few, and he gladly acknowledges his gratitude to Dr. Keith for the lucid explanation he has supplied of the complex and delicate mechanism involved. Those who are in a similar position, and are better acquainted with engineering than anatomical details, are recommended to begin with the second part.

A preliminary study of the anatomy of the cochlea and adjacent parts will teach the engineer with what materials he has to work and the scale of his drawings. The material is not rigid, and the scale is unfortunately so minute, that small errors in the measurement must exercise considerable influence in building up the machine. Such errors are inevitable, for the internal ear is a delicate and minute organ, encased in a thick and hard bone, which has to be dissolved away by acid before the cochlea can be prepared for microscopic examination. Distortion and contraction due to treatment by reagents in subsequent processes are unavoidable. As examples of the magnitudes of quantities entering into the problem, it may be mentioned that the effective maximum movement of the stapedial plate is fixed at 0·025 mm., and that of the basilar membrane at only 0·0055 mm. The diagrams of working models supplied by the authors are very illuminating, and assist in forming a correct mental picture. When one test of the sufficiency of the theory consists in submitting a mechanical explanation of all parts of the structure and in tracing the consequent movement, the importance of exact measurement is readily perceived.

The motive power available is derived from the pressure and rarefaction of the air waves, but the action of the cochlea may be compared with that of a hydraulic engine. The movement of the apparatus is effected by displacing fluids, more specifically, the motions of the stapes are due to the oscillations of two independent liquids, the perilymph and the endolymph. Sir T. Wrightson may be justified in treating these fluids as incompressible, and in regarding the communication of action through the whole mass as practically instantaneous, but he nowhere recognises a possible viscosity, a property that may exercise considerable influence on moving fluids in such confined spaces. But we may be quite sure such an obvious point has been considered, for the most conspicuous feature in the whole book is the care bestowed on every detail, and the patient examination of all causes that lead to vibrations and displacements of the stapes and membranes.

It cannot be too distinctly stated that the work assigned to the liquid in conveying the energy of the impulses of the waves constitutes one main difference between the theory due to the author and that of Von Helmholtz. The latter invoked resonance as the operating factor, finding his material in the varying lengths of the fibres of the basilar membrane. Sir Thomas Wrightson regards molar displacement of the liquid as the efficient mechanism. In the Helmholtz theory, a single wave is assumed to produce a single auditory stimulus when the tips of the cilia hit against the tectorial membrane. Sir Thomas considers each sound vibration as made up of four phases, and that each phase acting against an elastic resistance can give rise to a displacement stimulus. These four phases in a wave or sine curve are determined, respectively, by the "crests" and "troughs" and the points at which the curve crosses the axis of x, that is to say, the points at which the rate of change of the y ordinate is at a maximum. Dr. Keith seems to have had some hesitation in accepting the division of the whole cycle into four separate periods of pressure, and although he is whole-heartedly convinced of the propriety of this division, as of its necessity, a doubt may well be entertained whether the action produced at the axis crossings, would give rise to stimuli of the same nature and degree as those produced at the "crests" and "troughs." If this division of the wave be legitimate, then it is contended that the brain will receive sufficient data to make a complete analysis of a sound, however complex that sound may be. Very great ingenuity is displayed in the combination and resolution of sound waves, and no anatomical knowledge is required to follow the author's explanation that impulses caused by changes of pressure in the air correspond with the actual phenomena of compound tones which appeal to the brain. To follow the explanation of the manner in which the motions conveyed to the perilymph are identified with the various phenomena of sound, producing the sensations of pitch, loudness, and timbre of tone is, of necessity, a more difficult task, one calling for close attention that will, however, be amply repaid.

Dr. Keith in the clearest manner expresses his belief that Sir T. Wrightson has succeeded in establishing a really satisfactory theory of hearing. Having expressed our inability to judge of the anatomical evidence, it would be idle to add to this testimony, but we hope without presumption, we may be permitted to express our admiration of the manner in which the theory is presented, of the thoroughness with which each detail is discussed, of the completeness of the mental picture that is constructed, and to acknowledge the charm attaching to a sustained and consecutive argument.

Hand Grenades: A Handbook on Rifle and Hand Grenades. Compiled and illustrated by Major GRAHAM M. AINSLIE. London: Chapman and Hall, Limited. [Price 6s. net.]

THE gallant officer who has compiled this brief manual is no doubt a very competent authority on the training and handling of those who are entrusted with the dangerous duties of bombing. Of the construction and arrangement of the mechanism he is also probably quite able to speak fully, but prudence and a sense of responsibility have apparently contributed to render these descriptions bald and unsatisfying. One can easily understand that there are good reasons for reticence in dealing with so important an arm of the service, and Major Ainslie knows very well how far it is judicious or permissible to make the public acquainted with details. While admitting the necessity for caution, we must, however, be permitted to say that the amount of information conveyed is slender.

The object of the treatise is to assist students of grenade work to acquire a rapid and complete knowledge of the subject. The acquisition may be rapid as far as it goes; it will hardly be complete. Illustrations on which the author relies for the elucidation of many points may train the eye to external details, and enable one to determine to what class a particular grenade belongs, but intelligent curiosity on many points will remain unsatisfied. The time has not yet come when we may expect an exhaustive analysis of the relative merits of the various bombs that claim attention; when it is possible to discuss the value and appropriateness of different explosives that are recommended, or to inquire into the degree of certainty attending the use of the operative mechanism intended to ensure safety before, or explosion after, discharge as a missile. As little can we expect discussion of the varied constructions favoured by the different belligerents, or of the grounds for adoption of alternative designs. In fact, the author's ground is very limited by necessity, but he has deliberately narrowed the outlook by the curtness of his comment and the suppression of much that would have interested the lay public. Apparently, the object has been to instruct the bomb thrower in the use of the device with which he is provided, and to make him mechanically efficient in his several duties. Regarded as a manual of instruction to train the men about to be engaged in trench warfare or in house-to-house fighting, it may serve a useful purpose.

We are gravely informed that there are two

kinds of grenades, the distinguishing feature being the method of exploding, which may be effected either by percussion or ignition. Subdivisions of these main classes depending on the character of the explosive or the method of ejection are admitted, but apparently the army recognises only time grenades and percussion grenades. Minor variations due to the ingenuity of inventors are many, and some 15 forms are illustrated and described on a common plan. The following particulars are briefly given: The type, the weight, and the explosive employed; the character of the safety device, whose method of working must be inferred from the illustration; instructions for use and for firing. For some reason, special importance is apparently attached to the method of packing. While many important particulars are left unexplained, the author invariably explains with scrupulous care how many grenades are packed in a box and how many detonators are supplied.

The weight of the assembled parts varies between 1 lb. and 2 lb., and, consequently, for those thrown by hand the range of action is limited to a distance of from 30 yards to 50 yards. When it is necessary to obtain a greater range a form of purposely-adapted rifle is employed for projection, and by this means the effective distance is increased from 200 yards to 400 yards. The explosives used are variously lyddite, tonite, ammonal, and guncotton. The weight of the explosive charge is usually not mentioned, but the size of the chamber containing the explosive can generally be inferred from the illustration, and in one case in which ammonal is employed it is said to be 5½ oz. Ammonal is the form usually selected. It is said to be of Austrian origin and to possess the advantage of failing to detonate when struck by a rifle bullet. On the other hand, the material is very hygroscopic, and by reason of the collected moisture will occasionally refuse to detonate under any conditions. It would be interesting to have some authoritative information on the percentage of failures to explode, but this is a subject on which Major Ainslie is prudently silent.

The detonator is not an unimportant part of the mechanism, but the description of the various forms in use is very meagre, and not always intelligible. As an example of military briefness we may quote the entire description of one form of Service detonator. "No. 8, Mark VII. Copper tube open at one end painted red, marked on white label, No. 8, Mark VII, containing 32 grs. fulminate of mercury." The really valuable part of the description is probably to be found in the words "one end painted red, marked on white label, No. 8." Such information may prevent the grenadier applying a wrong kind of detonator, but the general public learns nothing and therefore cannot use its knowledge imprudently. The instructions for firing are given in the same brief way, and, we imagine, are merely the military words of command directing the manual exercise.

A chapter is given on the composition of a grenade squad with the duties detailed to each member. Plans for the most appropriate distribution of the men to secure the clearing of a trench from a flank, and arrangements suitable for a frontal attack, accompany the description. This chapter expresses or summarises the matured experience gained from many battlefields, and however necessary the instructions and the training may be, the deliberately considered preparation to make the attack as deadly as possible cannot but be ghastly reading. "The first man throws the bomb, the bayonet man enters the dug-out and completes its work . . . The N.C.O. will supervise the automatic filling-up of casualties in his squad by men from the squads in the rear." Gruesome and bitter tragedies are suggested in these simple instructions. We have not here the glamour of battle, the fierce contests that war correspondents describe or gloss, when passion is unrestrained and gallantry and valour mask the evils they create. The author describes the stealthy preparation, the cautious plan, the judicious strategy that will accomplish the most deadly end, but though it must be that offences come, the necessity for the deadly organisation is sad to contemplate.

Some remarks on the forms of French and German grenades are added, and a contrasted comparison of the peculiarities and merits of each would have been informative, but minute description is not the author's strong point, or it is thought more discreet to withhold any information that could be used for a sinister purpose. The unskilled is told how to make a German grenade harmless, or how to turn it to useful account against the enemy, very useful directions which are no doubt widely spread throughout the army, but by which it is hoped the civilian will never have occasion to profit. The book concludes with some general remarks on fuses, detonators, explosives, &c., but some of the information should be used carefully. For instance, we are told that "Carbolic acid is boiled sulphuric acid," a statement that has given us some perplexity, and one in which it is difficult to follow the distinguished officer.

BOOKS RECEIVED.

Practical Flying; Complete Course of Flying Instruction. By Flight-Commander W. G. McINNES, R.N. London: Temple Press, Limited. [Price 3s. 9d. net.]

Technical Handbook of Oils, Fats and Waxes. By PERCIVAL J. FRYER, F.I.C., F.C.S. Vol. I. *Chemical and General.* Cambridge: The University Press.

Mineral Enterprise in China. By WILLIAM F. COLLINS, Assoc.R.S.M. London: William Heinemann. [Price 21s. net.]

United States Bureau of Mines. Bulletin 146. *Technology of Salt-Making in the United States.* By W. C. PHALEN. Washington Government Printing Office.

An Inquiry into the Analytical Mechanism of the Internal Ear. By SIR THOMAS WRIGHTSON, Bart., M.Inst.C.E. With an Appendix *On the Anatomy of the Parts Concerned* by ARTHUR KEITH, M.D., F.R.S. London: Macmillan and Co., Limited. [Price 12s. 6d. net.]

Iron Corrosion: Anti-Fouling and Anti-Corrosive Paints. By LOUIS EDGAR ANDES. Translated from the German by CHARLES SALTER. Second English Edition revised and enlarged by H. B. STOCKS, F.I.C., F.C.S. London: Scott, Greenwood and Son. [Price 15s.net.]

Tidal Lands; A Study of Shore Problems. By ALFRED E. CAREY, M.Inst.C.E., and F. W. OLIVER, F.R.S. London: Blackie and Son, Limited. [Price 12s. 6d. net.]

Annual Report of the Department of City Transports of the City of Philadelphia for the Year Ending December 31, 1916. Philadelphia: Issued by the City.

Drainage Problems of the East. Being a Revised and Enlarged Edition of "Oriental Drainage." By C. C. JAMES. Bombay: Bennett, Coleman and Co., Limited. London: *The Times of India*, 99, Shoe-lane, E.C. 4.

Second Annual Report of the State Department of Health of Massachusetts. Boston: Wright and Potter Printing Company, State Printers.

The Design of Toothed Gear. By CLAUDE W. HILL, Assoc.M.Inst.C.E. London: Charles Griffin and Co., Limited. [Price 3s. 6d. net.]

Commonwealth of Australia Quarantine Service. Service Publication No. 14. *Storage and Distribution of Water on Ships.* By A. E. WADSWORTH. Melbourne: Albert J. Mullett, Government Printer.

The Marine Oil Engine Handbook. Compiled by the Staff of *The Motor Ship and Motor Boat.* Fourth Edition. London: The Temple Press, Limited. [Price 2s. net.]

BRITISH SCIENCE GUILD EXHIBITION.—The British Science Guild is organising a comprehensive exhibition of products and appliances of scientific and industrial interest which prior to the war were obtained chiefly from enemy countries but are now produced in the United Kingdom. The King is Patron of the exhibition, and the Marquess of Crewe, K.G., president. Among the vice-presidents are: The Prime Minister; Mr. Winston Churchill, Minister of Munitions; Sir Albert Stanley, President of the Board of Trade; Mr. H. A. L. Fisher, President of the Board of Education; Dr. Addison, Minister of Reconstruction; Lord Moulton; Lord Sydenham; Sir J. J. Thomson, President of the Royal Society; and other distinguished public men. The exhibition, which will be held at King's College, from about the first week in August until the first week in September, will show in the first place products chiefly imported from Germany before the war, but now made in this country; but it will also illustrate the remarkable developments that have taken place generally in our scientific industries. In many of these, as a matter of fact, Great Britain always excelled, and it is only our national quality of self-depreciation which has prevented the public from appreciating the fact that we were able to export to Germany apparatus and products embodying the highest scientific knowledge and technical skill. The exhibits will include: Chemical products; thermal, electrical and optical appliances; glass, quartz and refractory materials; photographic apparatus and material; surgical and medical appliances; papers and textile products. It is believed that the effect of the exhibition will be to have a most stimulating influence upon scientific and industrial research; the exhibits, and the demonstrations and lectures that will be given in order to explain them, will undoubtedly bring home to manufacturers, as well as to the general public, the great and growing part that science plays in industry. Further particulars may be obtained from the Organising Secretary, 82, Victoria-street, London, S.W. 1.

INDUSTRIAL NOTES.

THE Employers Parliamentary Council have issued a memorandum on the Employers and the Trade Boards Bill, a Bill which gives powers to the Minister of Labour to establish Wages Boards for the compulsory fixing of rates of wages which employers may legally pay. The Bill is an extension of the Trade Boards Act (1909), which is restricted to what were called "sweated industries," and is regarded as an attempt to fix permanently the inflated wages and artificial conditions of employment prevailing during the war. Under the principal Act, extensions could be made only by Provisional Order confirmed by Parliament, thus securing to all opponents the right of being fully heard. The present Bill transfers powers from the Board of Trade to an individual Minister, practically removes the safeguards given by the principal Act, deprives opponents of the right to be heard by Parliament against an Order, and places them at the mercy of a State Department without any power of resistance. The Employers Parliamentary Council are not aware of any reason for departure from the present course of procedure; they therefore urge the retention of the safeguards now existing, and submit that such a Bill should not be promoted in anticipation of the proceedings of the Joint Standing Industrial Councils to be established in the several industries, among the essential functions of which will be the fixing of rates of wages to correspond with the demand for "a higher standard of comfort generally"; and they further submit that to give general powers to a State Department to trespass upon the legitimate province of these bodies, which would possess a practical knowledge of the facts and circumstances relating to the industries they represent, is unwise and harmful, and likely to be strongly resented by the Joint Councils, who will naturally be jealous of their own authority and powers. If these Joint Councils cannot be trusted harmoniously to settle such a fundamental matter as the fixing of the rate of wages without their arrangements being subject to the decisions of a Statutory Wages Board, set up possibly at the instigation of a small number of discontented persons, their prestige will, it is contended, be destroyed, and the scope of their operations will necessarily be seriously diminished.

The Labour Party held last Saturday, in Liverpool, a special organisation conference for North-West Lancashire, when Mr. W. C. Anderson, M.P., said it was essential from the party point of view that they should build up an organisation on much stronger lines than they had in the past. The Labour party was looking forward to a great extension of its activities, and was determined to make a strong bid for power at the next election. In his opinion the Labour party had a tremendous opportunity now, if it knew how to take advantage of it. The war had destroyed many pre-war prejudices and preconceived notions, and it had destroyed, he believed, pre-war political parties. Therefore, in the rebuilding which was to come, Labour statesmanship had to be developed to a great degree. The big question that was going to dominate our politics for years to come was that of social reconstruction after the war, and the working people would want to have a voice in this. It was all very well to encourage people to emigrate, but he hoped they were going to make this country more attractive and a better country to live in in the future than in the past. The Labour party was putting forward a policy in regard to poverty, unemployment and destitution which, it was hoped, would put an end to these conditions. It had to see that the disabled man was not going to be exploited by the employer of labour, and that his pension was not going to be used in order to reduce the standard of wages for himself and his fellows, as was being done already in some cases. The Labour party proposed to have a national minimum of existence. He believed we were going to see a great extension of public ownership, and in an increasing degree democratic control of industry by the workers themselves. He did not want to go back to pre-war conditions between Capital and Labour, but he knew they could not get a new spirit unless machinery were built up through which it could express itself, and this was the aim of the Labour party.

A meeting of the British Federation of Iron, Steel, Tinplate and Metal Merchants was held at the Birmingham Chamber of Commerce on Wednesday, May 29, when Sir Johnstone Wallace (Newcastle) was elected chairman, Mr. J. Gray Buchanan (London) vice-chairman, and the appointment of Mr. C. T. Evennett as secretary was confirmed.

In response to inquiry the meeting was informed that, so far, no detailed reply had been received from the President of the Board of Trade to the protest that had been entered regarding the suggested intention to authorise the Commission Internationale de

Revitaillement, or a like organisation, to deal with private orders in this country after the war.

In view of the restrictions to trade, introduced by the Government on account of the war, the present and future position of merchants in the iron, steel, tinplate and metal trades was receiving the federation's earnest attention.

At the meeting it was decided that, in national interests, the general policy of the federation should be to endeavour to work in harmony with the Government Departments, but it was hoped that the control that existed at present, especially so far as private orders were concerned, should cease at the earliest possible moment.

In the course of an address Mr. J. Gray Buchanan stated that employers would have their hands full after the war in reconstructing their position with their employees, both in regard to the new relations between them on the lines of the Whitley Report, and the immensely increased production that must come when every workman did his best to turn out his maximum in order to do his part in the competition that was before the country. There was such a colossal field for reconstruction—which could only be covered by employers and labour—that the finding of new markets and wider and better home distribution might well be left to the merchants, who could be counted upon to continue doing their part for the Empire.

With their capital, the undivided assistance of the British banks, and the new-born resolve of the Government to take an interest in commerce, the country would be able to hold the immense volume of British trade which merchants had created.

Writing in *The Federationist* for May, Mr. W. A. Appleton says he is personally charged by Mr. Samuel Gompers to convey to the British people and Government, and particularly to Mr. Lloyd George, the assurance that all the American Federation of Labour and all who are directly and indirectly associated with it, are wholeheartedly behind President Wilson, and that they will back all the efforts of the United States Government to force a peace which shall destroy for all time the efforts of German militarism to enthral democracy. "We carry from America," adds Mr. Appleton, "renewed confidence and inspiration. Our sixty days amongst her people have shown us beyond any manner of doubt her capacity, her sincerity and her determination."

The committee of the Ministry of Reconstruction which is making an inquiry throughout the country from local authorities, builders, architects and others as to the probable demand for, and supply of, building materials during the reconstruction period two years after the war, has extended, until July 1, 1918, the date upon which the inquiry forms already sent out are to be returned.

The committee hopes that any authority, person or firm contemplating building works immediately after the war who has not received one of the committee's forms of inquiry will apply either directly, or through an architect, to the Secretary of the Building Materials Supply Committee, 6a, Dean's-yard, Westminster, for a form.

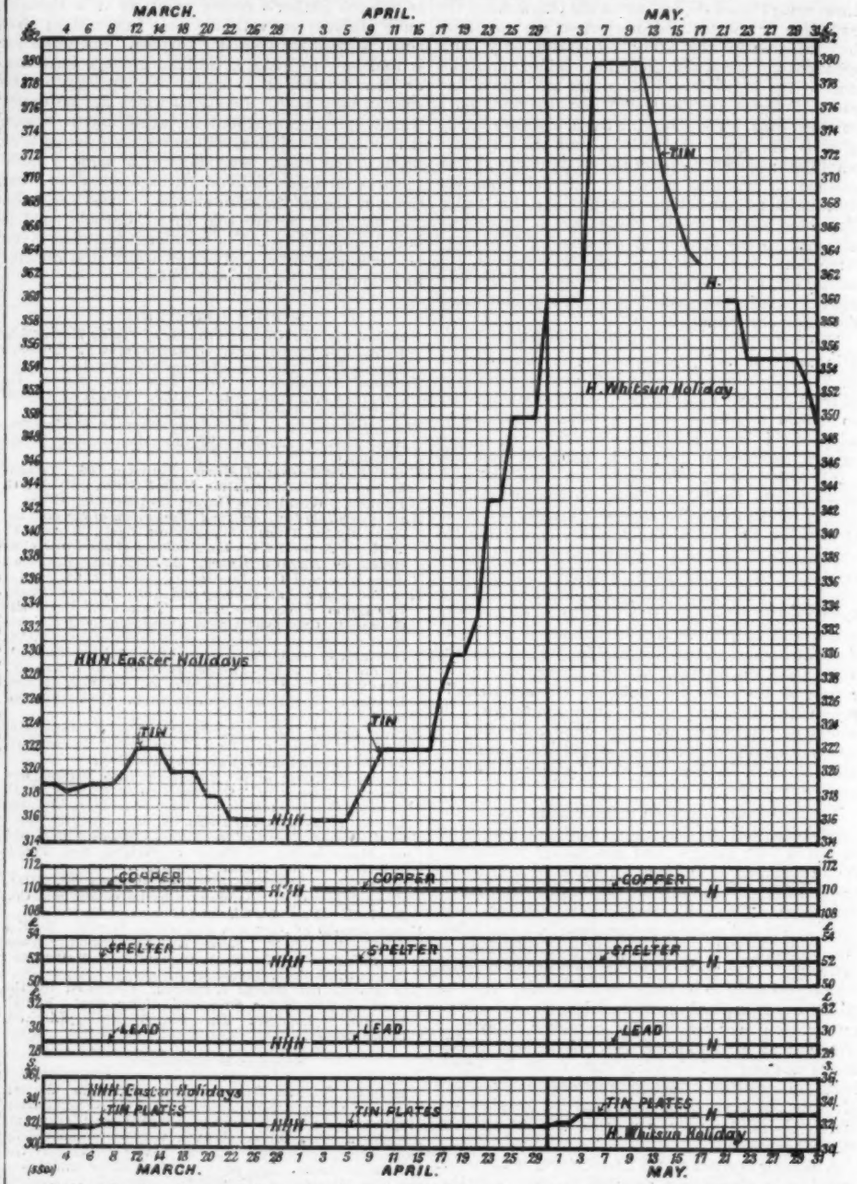
In cases where only sketch plans have been prepared and the preparation of complete plans and bills of quantities has been postponed until after the cessation of hostilities, it would appear that no materials will be required until at least six months after the war, and as regards these works it will suffice if the undermentioned particulars are furnished: County; description of building; estimated pre-war value of the work; estimated date of commencement of building; estimated duration of contract. Wherever possible, however, approximate quantities of materials needed should be furnished, especially in the case of building stone and bricks, steel and timber.

Materials needed for repairs, maintenance, &c., form the subject of a special inquiry, and particulars of these are not needed at present. In other matters, however, it is hoped that every effort will be made to complete forms of inquiry by the date specified. Unless the committee is made fully aware of the prospective needs of consumers, it will not be possible to estimate how far the available supplies will meet the demand, and its efforts to secure co-ordination may thus prove unsuccessful.

THE LATE MR. THOMAS AITKEN.—We regret to have to announce the death, which occurred on May 27, at Banchory, of Mr. Thomas Aitken, M.Inst.C.E., road surveyor for the Cupar District of the County of Fife for the last thirty-six years. Mr. Aitken was 61 years of age; he was born at Edinburgh and was educated at the High School there and at the Heriot Watt College. He thereafter entered the Engineering Department of the North British Railway Company, under the late Mr. Robert Bell, engineer for the northern district of that railway. After Mr. Bell's retirement, in about 1877, Mr. Aitken succeeded him as district engineer, and continued with the North British Railway until appointed road surveyor for the Cupar District of Fife in 1882. The introduction of the motor car led Mr. Aitken to devote a great deal of time and labour to the study of the construction and maintenance of highways as affected by this new means of transit. This eventually led to the invention by him of a machine to force tar and other viscous liquid under pressure into the surface of roads, thereby overcoming the dust nuisance and adding greatly to the life of the highways. At the International Competition held under the auspices of the Road Surveyors' Association of Great Britain, at Staines, near Windsor, in 1907, Mr. Aitken's machine gained for him the gold medal and a prize of 100 guineas. Shortly afterwards the Tar Roads Syndicate, Glasgow, was formed, Mr. Aitken being managing director. Mr. Aitken's invention was patented in Great Britain, the Colonies, the Continent and the United States; the patent rights in several countries have since been sold. He subsequently formed a small company for developing the patent and working the machine in this country, and he treated a large mileage of highways, particularly in the West of Scotland, with his process. Frequent testimony has from time to time been borne as to the efficiency with which he carried out his work as a road surveyor and about eight or nine years ago he was requested to go to America by General Dupont, of Wilmington, to advise and assist in the formation of an important State road from Wilmington to Georgetown. He was a frequent contributor of articles on road-making to engineering and other technical journals. He also wrote a book on the "Construction and Maintenance of Roads," which has now become a standard work, and has gone through two editions. At the time of his death Mr. Aitken was engaged in revising proofs for a third edition.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagram above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7, 1916, the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig iron was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45, vol. cii.)

EFFECT OF MASS ON HEAT TREATMENT.*

By E. F. LAW, Assoc.R.S.M., Manchester.

SCIENTIFIC research during the last twenty-five years has not only given us a complete equilibrium diagram of the carbon steels, but has also given us information regarding the physical phenomena occurring in a vast number of special steels with changes in temperature.

With this information at our disposal it is possible to determine the theoretically correct heat treatment for any steel, and little difficulty is experienced in dealing with small masses. Unfortunately, however, the heat treatment of large masses of steel presents many difficulties which do not exist in the case of small masses. It is well known, for example, that the molecular changes which occur in steel are not fixed and unalterable, but depend, both as regards their magnitude and the temperatures at which they take place, on such conditions as the rate of cooling and the initial temperatures to which the steel has been heated. The difficulties met with in the heat treatment of large masses of steel lie, not in the lack of knowledge concerning the properties of the steel, but rather in the practical application of that knowledge. And it is here that the manufacturer is apt to expect too much from the scientific worker, who is usually told that it is an easy matter to deal with ounces, but very different when tons have to be treated. Sometimes the remark is made as though it settled the matter and nothing more need be said, and sometimes the scientist is even expected to teach the manufacturer his business.

Such an attitude is not only untenable, but unfair to the scientific worker who, even if he has the resources of a works at his command, has not the training necessary to employ them to advantage. The responsibility rests with the manufacturer; and if he fails to apply the knowledge which science places at his disposal for the benefit of himself and his shareholders, he has only himself to blame.

This, however, is a question which need not be discussed here. The more important problem is to endeavour to obtain information which will enable us to understand the changes which actually take place in a mass of steel during the stages of its treatment. Consider, for example, some of the questions which at once arise when large masses are to be treated. How long does it take for a mass of steel to become uniformly heated in the furnace? To what depth does the effect of oil tempering extend? To what depth is it possible effectively to harden steel by quenching in water? Obviously the shape of the mass to be treated is an important matter, and every case must be dealt with individually when the conditions under which the treatment is to be carried out are known. But even in the simplest cases it must be admitted that our knowledge of the subject is very imperfect.

In order to obtain some information concerning the changes taking place in the interior of a mass of steel during treatment a series of experiments were carried out, and the results are published here in the hope that, although far from complete, they may be of interest and possibly of value to some of the members of the Institute.

Throughout the experiments the object aimed at was the elimination of as many variables as possible, so that the results obtained might be comparable.

A 25-in. square ingot 10 ft. in length and weighing nearly 10 tons was cogged down to 18 in. square and was then cut into 18-in. lengths, thus giving a number of 18-in. cubes, each weighing approximately 14¼ cwt. Only those cubes representing the soundest part of the ingot were employed in the experiments. Three analyses taken from different parts of the ingot gave the following results:—

		1.	2.	3.
Carbon	... ...	0·340	0·350	0·340
Silicon	... ...	0·190	0·196	0·190
Sulphur	... ...	0·022	0·022	0·021
Phosphorus	...	0·030	0·034	0·032
Manganese	...	0·730	0·740	0·740
Nickel	... ...	0·200	0·200	0·200

Heating and cooling curves were also taken, and are reproduced in Fig. 1.

In each experiment three thermocouples were inserted in the cube to be treated—one in the centre, one 4½ in. from the centre (*i.e.*, exactly half-way between the centre of the cube and the centre of one side), and one ½ in. deep in the centre of one surface. These couples were inserted before the cube was placed in the furnace and remained in position throughout the entire treatment, continuous records being taken.

As it was desired to obtain results of some degree of accuracy every effort was made to reproduce laboratory conditions as closely as possible. For this reason platinum-platinum rhodium couples were used, and the records were taken on sensitive suspended coil galvanometers. These were of the high-resistance type; but as copper connections of considerable length were necessary, the instruments were always calibrated with the length of connection actually used in the experiments so as to avoid any error due to variation in external resistance.

The thermocouples, insulated by fine quartz tubes, were inserted in holes ¼ in. in diameter drilled in the cubes, and were then carefully plugged in position with asbestos.

The cubes, supported on knife-edges, were heated in gas-fired "treatment" furnaces in which the flame did not come in contact with the cube; and in every case the heating was carried out in the same way. The furnace was raised to a temperature of 1,650 deg. F. (900 deg. C.), the cube "charged," and the furnace then maintained at a constant temperature of 1,650 deg. F. (900 deg. C.) until the cube attained the same temperature as the furnace. These furnace temperatures were measured by means of a platinum-platinum rhodium thermocouple and galvanometer similar to those used in taking temperatures of the cube. The heating curves in each case were practically identical, and it is only necessary to reproduce a single example. As a matter of some interest, however, although not directly concerned with the subject under investigation two series of curves are reproduced (Fig. 2), one set showing the furnace readings, the other the heating curves of the steel cubes. In one case, shown dotted, the furnace was heated with ordinary producer-gas while in the other, shown in black, the furnace was heated with "Mond" or "recovery" gas.

Perhaps the most noticeable feature about these curves is the rapidity with which the heat penetrates to the centre of the cube. At 130 minutes from the time of charging the centre and half-way are almost at the same temperature; but at this point the absorption of heat due to the Ac change causes a greater lag at the centre than elsewhere, and the two temperatures do not approach one another again till the lapse of another 70 minutes.

After being in the furnace for about 4½ hours, the cube attains a uniform temperature throughout its mass which practically coincides with the temperature of the furnace. When this stage was reached one of the cubes was drawn from the furnace and placed on knife-edges

Fig.1. HEATING AND COOLING CURVES.

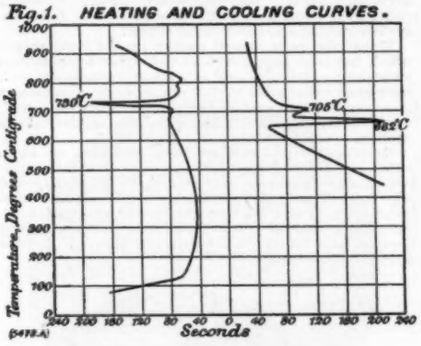


Fig.2. HEATING CURVES.

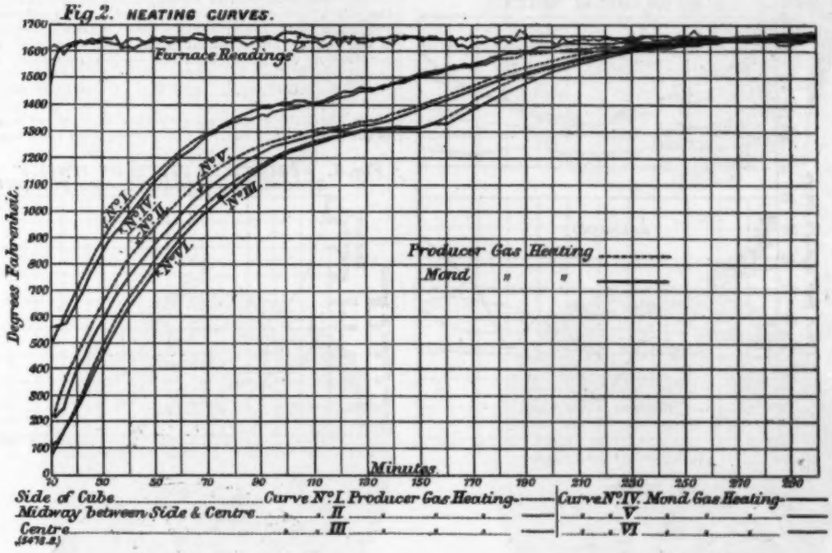
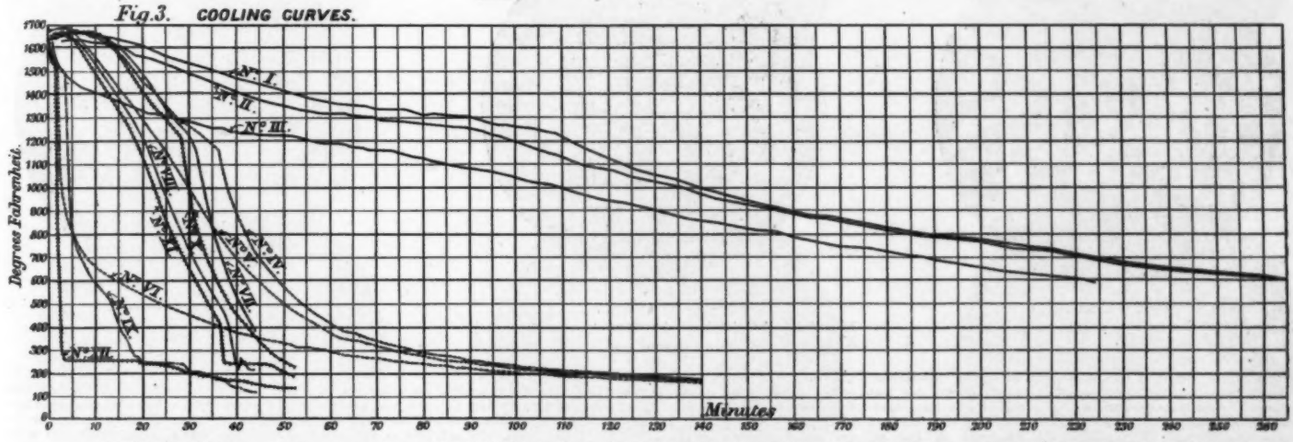


Fig.3. COOLING CURVES.


Degrees Fahrenheit.
Minutes
N°. I.
N°. II.
N°. III.
N°. IV.
N°. V.
N°. VI.
N°. VII.
N°. VIII.
N°. IX.
N°. X.
N°. XI.
N°. XII.
Centre of Cube ... Curve N° I Cooled in Air ... Curve N° IV Oil-quenched ... Curve N° VII Water-sprayed ... Curve N° X Quenched in Water at 55°
Midway between Centre & Side ... II ... V ... VIII ... XI
Side of Cube ... III ... VI ... IX ... XII
(5478.C)

*Paper read before the Iron and Steel Institute, Friday, May 3, 1918.

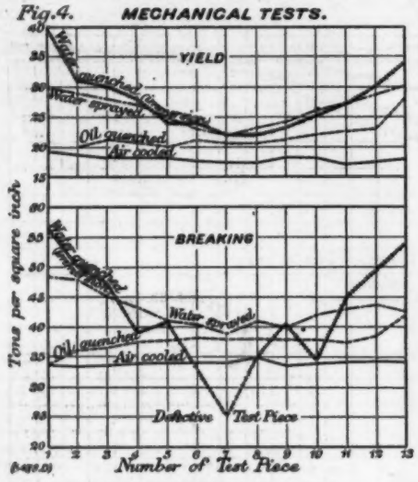
to cool in the air. The curves I, II, III, representing the rate of cooling, are reproduced in Fig. 3 and require no explanation. The cooling takes place very slowly and as in the case of the heating curves, the corresponding evolution of heat is most marked in the centre of the mass.

A second cube after being heated to 1,650 deg. F., as already described, was drawn from the furnace and plunged in oil in the usual way. Mineral oil was used having a specific gravity of 0·897 and flash point 378 deg. F. (192 deg. C.).

The curves IV, V, VI, obtained are shown in Fig. 3, together with all the cooling curves, so that the relative rates of cooling under different conditions can be readily compared.

To those who are in the habit of oil-hardening large forgings, and know how long it takes for these to cool in the oil, the rate of cooling may seem rather surprising.

Fig. 4. MECHANICAL TESTS.

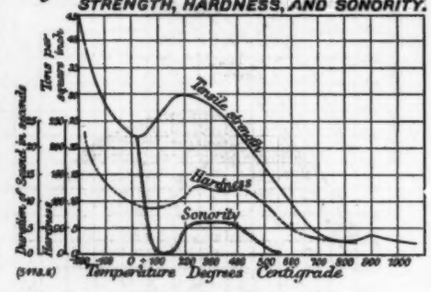


(232 deg. C.), when there is a sudden acceleration in the rate of cooling, followed by an equally abrupt halt at about 250 deg. F. (120 deg. C.). Somewhat similar features are shown in the curve representing the cooling of the outside of the cube.

As it was thought possible that the cooling might be uneven on account of the water only impinging with full force on two sides of the cube, a further experiment was carried out in which the cube was plunged into water at 55 deg. F. (13 deg. C.). In this case the cooling was somewhat more rapid; but the curves X, XI, XII, showed exactly the same characteristics as in the previous experiment.

The essential features of the curves obtained by each method of cooling are clearly shown in Fig. 3. The extreme slowness of air cooling as compared with either oil or water cooling is too obvious to require comment. A comparison of the curves obtained by oil and water cooling, however, is of greater interest. The rapidity of the cooling in oil has already been referred to; but the important difference between the two methods of cooling is to be found in the almost sudden slowing up of the cooling in oil shown in the lower ranges of temperature as compared with the cooling in water. For example, the time required for the centre of the cube to cool from 1,650 deg. F. (900 deg. C.) to 1,000 deg. F. (538 deg. C.) (a temperature well below the critical range) is almost the same, whether oil or water is used as the quenching medium. In cooling from 1,000 deg. F.

Fig. 5. RESULTS OF TESTS OF TENSILE STRENGTH, HARDNESS, AND SONORITY.



tempering," which occurs in the lower ranges of temperature during oil-quenching.

Sections were cut from the test-pieces and examined microscopically. The photographs in Nos. 1 to 12 show the characteristic appearance of magnifications of 100 diameters. The entire series are pearlitic, as might have been expected from the mechanical tests, and under higher magnifications they all, with one exception, show well-developed laminated pearlite. The exception is to be found in the surface of the cube quenched by plunging in water. In this case very little free ferrite is to be seen, and it is evident that the transformation has been very nearly arrested. This is confirmed by the fact that the surface of this cube was the only part which presented the slightest difficulty in machining.

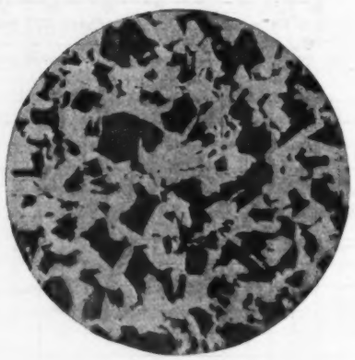
The abrupt halt in the neighbourhood of 250 deg. F. (120 deg. C.) shown in the curves obtained from the water-cooled samples was totally unexpected and too striking to be passed over without notice. The question at once arises: Is the break in the curve due to some change taking place in the steel itself, or is it in some way connected with the water used in quenching?

At first sight the latter explanation seemed the more likely; but on further examination it does not appear to be supported by the facts. If it is due to the possible entry of water into the hole occupied by the thermo-couple, why does the temperature remain constant for so long a time, and at 50 deg. above the temperature of boiling water? And why does the same thing not occur in the case of the couple in the centre? On the other hand, if it is due to the formation of an envelope of steam round the cube which hinders the cooling, it is extremely unlikely that this would cause so sudden a halt in the cooling at a distance of 4¼ ins. from the surface and have no effect in the centre.

If the change is caused merely by the recalescence which has been suppressed at the higher temperature, eventually asserting itself at a lower temperature, it is somewhat remarkable that it should occur so regularly at a constant temperature both on the outside and half-way curves, considering the difference in the rate of cooling.

Experiments repeated on 18-in. and also on 12-in. cubes showed that, whatever the causes of the phenomenon, it occurred with remarkable regularity and was not affected by reasonable variations in mass. Attemps were also made to locate the point during oil-quenching, and in spite of the slow rate of cooling through this range of temperature there is distinct evidence of its existence.

No. 1.—Outside.



No. 2.—Midway.

No. 3.—Centre.

18-inch Steel Cube, heated to 900° C., and air cooled. Magnified 100 diameters and reduced by one-tenth.

It must be pointed out, however, that the conditions under which this experiment was carried out are not strictly comparable with average works practice, inasmuch as the volume of oil used was so great that no perceptible rise in temperature occurred in the oil itself. Although these conditions do not usually obtain in works practice, they were deliberately aimed at in these experiments in which the elimination of as many variables as possible was considered desirable.

Even in the centre of the cube cooling takes place rapidly; but the evolution of heat at the Ar point is very noticeable. In the half-way curve, however, there is not the slightest indication of any recalescence. If it occurs (and presumably it does) it appears to be so evenly balanced by the conduction of heat to the outside that no change in the direction of the curve is noticeable. In fact, if the half-way curve were considered by itself it might be supposed that the steel possessed no critical point at all.

A third cube, after heating to 1,650 deg. F., as in the preceding cases, was placed on knife-edges and cooled by spraying water at a pressure of 10 lb. per square inch on the upper and lower surfaces. By this means a large volume of cold water comes into contact with the heated metal and, as might be expected, the cooling takes place more rapidly than in oil. In some respects, however, the curves VII, VIII, IX are similar. The centre curve again shows an evolution of heat and is not unlike the oil-hardening curve, although the rate of cooling through the lower ranges of temperature is more rapid. On the other hand, the half-way curve is totally different to that obtained by oil-quenching. There is no sign of recalescence in the upper ranges, and the temperature falls evenly until about 450 degr. F. (538 deg. C.) to 600 deg. F. (316 deg. C.), however, the cube cooling in oil requires twice the time, and in cooling from 600 deg. F. (316 deg. C.) to 300 deg. F. (149 deg. C.), it requires nearly our times as long. The differences are even greater on the outside of the cube, the oil-cooled surface taking six times as long as the water-cooled surface in cooling from 600 deg. F. to 300 deg. F.

It may be observed as a fact of some interest that both in oil and water cooling there is a period during which the metal in the centre of the cube is cooling down more rapidly than the metal midway between the centre and surface.

MECHANICAL TESTS.

From each of the experimental cubes, after cooling, a section 1 inch thick was cut through the centre, and from this section 13 test pieces were machined, so that mechanical tests could be taken representing the steel from outside to centre of the cube. The results are plotted in Fig. 4.

As might have been expected, the 13 results from the air-cooled cube gave practically identical results. In the case of the oil-quenched cube the breaking stress and yield are both raised, while the elongation is lowered, to almost the same extent in every test, the curves approaching a straight line. In other words, the effect of oil-quenching is as apparent in the centre of the cube as on the outside. In contrast to the results obtained by oil-quenching, those obtained by water-quenching show a very decided variation from surface to centre of the cube; and this is most marked in the case of the cube plunged in cold water. The effect of the quenching is uneven, and the tests suffer from the lack of what might almost be described as "automatic

It would appear, therefore, that the phenomenon is in some way connected with the steel itself, and, acting on the principle laid down by La Rochefoucauld, that "on doit moins s'appliquer a faire naistre des occasions qu'a profiter de celles qui se presentent," it was decided, even at the risk of evolving yet another theory of hardening, to carry the investigation a step further.

At this stage, however, it is of interest to recall the results obtained by numerous investigators on the properties of iron and steel at low temperatures.

As far back as 1850 Fairbairn showed that iron possessed a maximum resistance to fracture at 250 deg. C. and this has since been frequently verified both for iron and steel. It has also been shown that this maximum resistance is preceded by a minimum which occurs at about 120 deg. C.

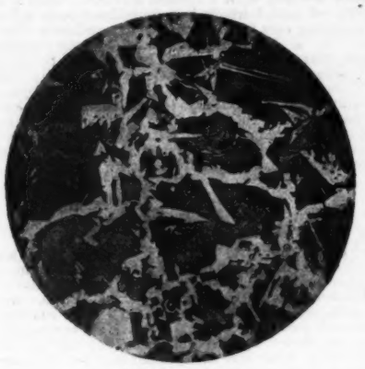
Since the work of Fairbairn these results have been confirmed by Pisati and Saporita Ricca, Andre Le Chatelier, Thurston, Charpy, Adamson, Joesell, Kirkaldy Bach, Rudiloff, Le Blant and Huntingdon.

Robin* has shown that steel possesses a maximum hardness at about 250 deg. C., and a minimum at about 100 deg. C.; and, in a masterly research which has not received the attention which it deserves, he has shown that steel loses its sonority (i.e., ceases to emit a note when struck) at temperatures of 100 deg. to 150 deg., but recovers its sonority at higher temperatures, the maximum being reached at 250 deg. Both as regards hardness and loss of sonority (aphonia), variations in the percentage of carbon only affect the results in degree.

* Iron and Steel Institute Carnegie Scholarship Memoirs, 1911, vol. iii., pp. 125–214.

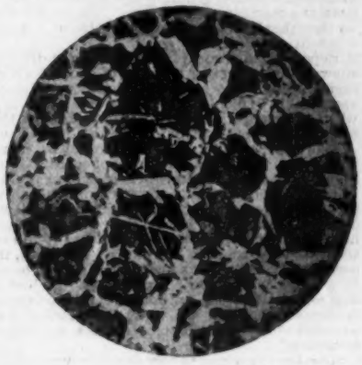
The temperatures at which the phenomena are observed remain constant.

In Fig. 5 are plotted for the sake of comparison the results of tests of tensile strength, hardness and sonority The tensile strength curve must be regarded as more or less approximate, and has been arrived at by combining the results obtained by Hadfield at low temperatures (−200 deg. to + 18 deg.), Huntington at



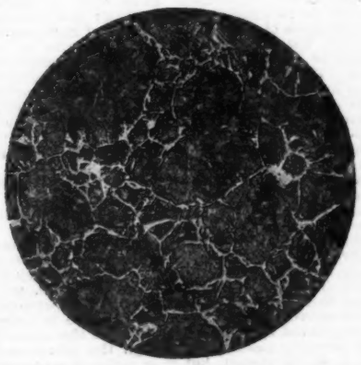
No. 4.—Outside.

No. 5.—Midway.



No. 6.—Centre.

18-inch Steel Cube, heated to 900° C. Oil hardened. Magnified 100 diameters and reduced by one-tenth.



No. 7.—Outside.

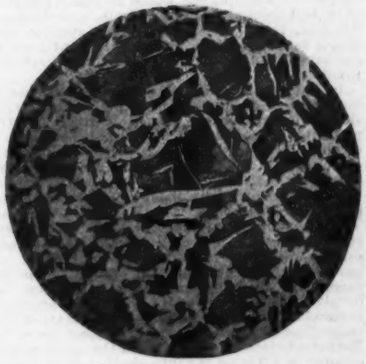
No. 8.—Midway.

No. 9.—Centre.

18-inch Steel Cube, heated to 900° C. Sprinkled on Sprinkler. Magnified 100 diameters and reduced by one-tenth.

No. 10.—Outside.

No. 11.—Midway.



No. 12.—Centre.

18-inch Steel Cube, heated to 900°C. Quenched in water tank. Magnified 100 diameters and reduced by one-tenth.

medium temperatures (14 deg. to 427 deg.), and Rosenhain at high temperatures (656 deg. to 1,080 deg.). The hardness curve is that given by Robin for a steel containing 0·12 per cent. carbon in an annealed condition, and the sonority curve is given by the same authority for an annealed steel containing 0·4 per cent. carbon.

In discussing the results of his researches Robin asks: "Would it not be simpler to admit for the present that the occurrences take place as though alpha iron underwent an allotropic transformation from the state alpha 1 to the state alpha 2 at about 120 deg., or, more accurately still, between 100 deg. and 250 deg.?"

He does not, however, entertain the idea of using the recognised thermal methods for the detection of molecular transformation. "The thermal method does not admit of any transformation in the iron being detected at these temperatures." And again, "As the transformation of alpha 1 iron into alpha 2 iron can only be detected by mechanical tests. . . ."

With that sound judgment which is in keeping with the whole of his work, Robin concludes: "While waiting for a method which would permit of the existence of these points being definitely established or disproved by means which would not alter the state of the metal itself, it is better to leave in the condition of an hypothesis this suggestion of the existence of fresh varieties of iron."

Osmond, however, with the characteristic readiness of a great mind to receive and welcome new facts, considered that something more than a hypothesis was necessary; and in discussing Robin's work he wrote: "It would therefore appear that a transformation not hitherto recognised as distinct from the transformation A2 and A3 occurs. This transformation commences at about 100 deg. (on heating) and appears to be progressive. The fact that, up to the present, no corresponding thermal phenomenon has been established is no vital objection to this suggestion, as the thermal effect may be within the range of experimental error, and is probably distributed over a large temperature interval."

"It appears necessary," he adds, "by reason of the new facts which are accumulating, and for which existing theories no longer afford sufficient explanation, to add a new factor to those which it has been necessary, from time to time, to introduce into the chemical history of iron. In order to shorten the inevitable period of uncertainty it would be desirable to renew, on identical samples, the investigation of the whole of the physical properties of this metal between ordinary temperature and 700 deg."

If any argument were needed to support Osmond's plea for further research it can be found in the fact, well known to every manufacturer and user of steel, that this metal undergoes peculiar changes and possesses properties at a "black heat" which have never been adequately understood or explained.

The possibility of the apparent transformation at 120 deg. now detected by thermal methods being identical with that found by previous observers by mechanical methods at once presents itself; and it was therefore decided to continue the investigation from the thermal standpoint with the object of determining whether the transformation is real, and if so what is its significance. For this purpose the large cubes used in the earlier experiments were abandoned and 2-in. cubes substituted

as they could be more readily handled and the experimental work could be transferred to the laboratory.

Naturally the accelerated rate of cooling of the small cubes altered the conditions of the experiments, and it was now found that the break in the curve at 120 deg. C. was very noticeable in the oil-hardening, whereas in the water-quenched cube no break in the curve was observed. Further, the water-quenched cube was too hard to machine, and after grinding and polishing was found to possess a martensitic structure. The oil-quenched cube on the other hand, was readily machined and possessed a pearlitic structure.

Repeated experiments on quenching at different rates showed that whatever the rate of cooling through the higher ranges of temperature down to 300 deg. C., no appreciable hardening effect was obtained. It is only when the rapid cooling is continued through the lower ranges of temperature that the hardening is effective.

This can be shown by quenching steel in water at varying temperatures. The rate of cooling through the higher ranges of temperature is almost as rapid in hot water as in cold, whereas in the lower ranges of temperature the rate of cooling in hot water is slower than in cold. This is quite in accordance with the fact which has been frequently demonstrated that steel cannot be effectively hardened in hot water. Moreover, it is also a well-known fact that a hardened steel can be softened by heating at very low temperatures. So low, in fact, that some have argued (although there is no experimental evidence to support the view) that hardened steel is unstable at atmospheric temperatures, and is gradually softening.*

Since the experiments here described were carried out a short paper has been published by Dejean, who has observed the same low point in the cooling of steel, and apparently arrives at similar conclusions.

Starting with tool steels Dejean† finds that these show a critical point between 700 deg. and 800 deg., and a second point about 400 deg.; and continuing his investigations on carbon steels of 1·13 per cent. and 0·74 per cent. carbon, he finds that on quenching in oil or water these show a critical point "between 700 deg. and 500 deg.," which he calls A, and a second point "below 200 deg." which he calls B. He concludes that point A indicates the presence of pearlite or troostite, and point B that of martensite.

There appears to be some justification for the assumption that this low point is inherent in the iron itself, and that, as in the case of the higher critical point, it re-acts on the carbon and in fact fixes the limit beyond which the carbon transformation cannot take place.

If these conclusions are correct (and much work will be necessary before they can be established with absolute certainty) the existence of this low critical point throws new light on the phenomenon of hardening in steel.

Following the excellent work of Beilby, some of his more enthusiastic admirers have endeavoured to attribute the hardness of metals, whether produced by quenching or cold working, to the existence of an extremely hard amorphous cement formed between the crystals or between the slip planes of the crystals themselves.

Such an explanation must be curiously unconvincing to an average mind. Would it not be equally logical to attribute the hardness of a silica brick to the hardness of the minute quantity of binding material which exists between the particles of silica? It is a human failing, however, always to seek a complicated explanation where a simple one would do equally well, in spite of the fact pointed out by that distinguished metallurgist Sauveur, that "the theories that survive are those which can be grasped by an intelligent man without excessive stretch of the imagination or strain of the mind."

In most of the published work on the hardness of metals no consideration is taken of any property other than volume; and in discussing the properties of a metal it is only thought necessary to consider the volume of the atoms (always assumed to be spheres), their arrangement, and sometimes the space between them. Surely the molecules, atoms, ions, or ultimate particles by whatever name we choose to describe them, must possess definite physical properties other than the occupation of space; and it would be more reasonable to regard them as microcosms which, if they cannot be said to "live and move and have a being," at least move or are capable of moving. As Graham pointed out more than fifty years ago, "solidification may not involve the suppression of either the atomic or the molecular movement, but only the restriction of its range"—a truth demonstrated many years later by Roberts-Austen when he showed that solid metals were capable of diffusing one into another at ordinary atmospheric temperatures.

If we do not admit the possession by the atoms of definite properties, how can we account for the formation of chemical compounds, or explain that mysterious force which is vaguely referred to as "chemical affinity"? Take, for example, the three metals—gold, silver and aluminium. All have similar atomic volumes, and all are relatively soft. The alloys of gold and silver form a simple series of solid solutions which, although not hard, are considerably harder than the constituent metals. The alloys of gold and aluminium, on the other hand, give rise to a hard and brittle compound. Can this be explained merely by supposing certain arrangements of the atoms?

The property of hardness as known to us and as measured by sclerometer, scleroscope, or Brinell test, is merely the resistance offered to movement, and the hardness of a body is not due to the position of the atoms, but to their inability to change their position. A sack of grain loosely filled is relatively soft, but twist the neck of that sack until the individual grains are incapable of moving over one another and the hardness of the mass increases very materially. As measured by the methods referred to, the hardness of water is inappreciable. Restrict the movement of the molecule (in other words, freeze it) and its hardness is considerable.

Moissan has shown that carbon under great pressure crystallises in the form of the diamond—the hardest substance known to us—and the experiments of Dewar have shown that even hydrogen can be obtained in the solid form and possessing some degree of hardness.

It must be conceded then that the atom is hard, possibly incompressible and indefinitely hard. It follows that the more the movement of the atoms is restricted the more closely will the hardness of the body approach the hardness of the atom.

Whether the restriction of movement is due to work applied externally as in the case of cold working, or to work applied internally as in the case of a molecular change (more especially one involving expansion) taking place at a low temperature, the result will be an increase in the hardness of the mass.

In conclusion, the author wishes to express his indebtedness to Mr. D. Newton, Dr. J. H. Andrew and other members of the staff at Openshaw, who have given him much valuable assistance and have never failed to overcome the many practical difficulties encountered in the experimental work.

* Brush and Hadfield, "Spontaneous Generation of Heat in Recently Hardened Steel," Proceedings of the Royal Society, 1917, vol xciii.

† *Comptes-Rendus*, July 30, 1917.

HIGH-SPEED INTERNAL COMBUSTION ENGINES.*

By HARRY R. RICARDO, B.A., Associate Member.

(*Concluded from page* 623.)

APPENDIX I.

RANGE OF MIXTURE STRENGTH AVAILABLE WITH PETROL.

COMMERCIAL petrol consists generally of a mixture of hydrocarbon ranging from pentane C_5H_{12} to C_9H_{20}; they all belong to the paraffin series, and have the characteristic formula $C_n H_{2n+2}$. The weight of air required for the complete combustion of 1 lb. of petrol may be obtained from the formula :—

$$A = 0.0116 \left(\frac{C + 3 (H - \frac{1}{8} O}{100} \right)$$

Where A is the weight of air in pounds.
C is the percentage of carbon present.
H is the percentage of hydrogen present.
O is the percentage of oxygen present.

From this it will be seen that 1 lb. of petrol of average composition requires approximately 15 lb. of air for complete combustion. At a temperature of 0 deg. C. the volume of 1 lb. of air is approximately 12·4 cub. ft., while the volume of 1 lb. of petrol vapour at the same temperature is only about 4·17 cub. ft. By volumes, therefore, the proportion of petrol vapour to air required to give complete combustion is 1 : 44·5, or about 2·25 per cent.

Taking the lower calorific value of petrol as 18,600 British thermal units per pound,† the heating value of an air-petrol mixture giving complete combustion may be taken as just under 100 British thermal units per cubic foot. Under atmospheric pressure the weakest mixture which will ignite at all is about 1·1 per cent. petrol vapour measure by volume, but with such a mixture the rate of burning is so low as to be quite useless. The lowest proportion which will ignite under pressure does not appear to have been determined with any accuracy, but there is a good reason to believe that under the combined effects of high pressure and great turbulence slightly weaker mixtures can be ignited. In practice, however, these weak mixtures are of no value, for although the flame temperature is low and the theoretical efficiency should therefore be high, this advantage is altogether discounted by the fact that ignition is slow and incomplete. In practice the highest thermal efficiency is obtained with a mixture density of from 80 British thermal units to 90 British thermal units per cubic foot, and it is found that any attempt to work with a weaker mixture merely leads to incomplete combustion, and the consequent continuance of burning during the exhaust stroke, with the result that the fresh charge is ignited on entry and fires back through the inlet valve. The extreme range therefore between the weakest mixture which can be usefully employed and that which consumes the whole of the oxygen present, and therefore yields the highest flame temperature, is only from about 80 British thermal units to 100 British thermal units per cubic foot, a very narrow range when compared with town gas, which ranges from about 45 British thermal units per cubic foot up to about 80 British thermal units over the whole of which range combustion is practically complete. At the other end of the scale we find that with petrol the richest mixture which will give sufficiently rapid combustion to be of real value is about 130 British thermal units per cubic foot. In this case the excess of fuel for which there is no oxygen for combustion is about 30 per cent., and the efficiency is therefore reduced in that proportion, but if we consider the mean pressure obtained with such a mixture it is found that it is slightly greater than when using a mixture giving complete combustion. This is to be accounted for by the fact that when using such a rich mixture the actual flame temperature is slightly lower, also the specific volume of the products of combustion is very considerably increased, with the result that the efficiency reckoned only on that portion of the fuel which is completely burnt is somewhat higher than when working with a normal mixture. This is a peculiarity of petrol which has sometimes been made use of in racing cars in which fuel consumption is of no account. It is common knowledge among racing motorists that the power of an engine can be very slightly increased by working with an abnormally rich mixture, and it has been found that when employing such a mixture it is possible also to raise the compression. This is probably to be accounted for by the fact that the residual exhaust products left in the combustion chamber contain a larger proportion of carbon and steam, both of which reduce the tendency to detonation.

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders at Newcastle-upon-Tyne, on April 30.

† Authorities differ as to the exact lower calorific value of petrol, but the figure 18,600 British thermal units per pound is probably very nearly correct.

APPENDIX II.

VOLUMETRIC EFFICIENCY.

When considering the volumetric efficiency of an engine it must be borne in mind that it is not the volume of the air or working fluid taken into the cylinder that is of importance, but rather the weight of charge. An engine such, for example, as a paraffin engine running on vaporised fuel may have a very high volumetric efficiency as shown by the indicator, but the actual weight of charge taken into the cylinder may be relatively small owing to the pre-heating which it has undergone in the vaporiser. In spite of this, it is customary in certain technical works to define the volumetric efficiency as the ratio between the pressure in the cylinder at the end of the suction stroke and the outside air, no account being taken of the temperature. In the author's opinion such a definition is liable to be misleading; as a measure of the correctness of the valve setting it is of course quite satisfactory, but it is not necessarily of value as an indication of the actual power output that may be expected. The author prefers to state the volumetric efficiency in terms of standard pressure and temperature which is equivalent to stating it in terms of weight. The actual volumetric efficiency attainable depends upon :—

1. The temperature of the working fluid as it enters the cylinder.
2. The resistance to its entry due to restrictions in the valves and piping.
3. The residual pressure of the exhaust products in the clearance space.

Neither the temperature nor the bulk of the exhaust gases have any influence on the volumetric efficiency whatever, that is to say, the volumetric efficiency is absolutely independent of the compression ratio, provided that there is no appreciable exhaust back pressure.

The actual volumetric efficiency obtainable is somewhat complicated by the fact that neither the exhaust nor the incoming gases pass through the valves and pipes in a steady stream, but in a series of waves or pulsations which may or may not synchronise with the closing of the valves; consequently it is quite possible to obtain an appreciable reduction in the exhaust below the atmospheric pressure at the end of the exhaust stroke, and it is conceivable that a slight supercharge above atmospheric pressure might be obtained at the end of the suction stroke. For the purpose of the present calculations, it will be as well to assume that no pulsations occur, and that the pressure of the exhaust gases is exactly atmospheric. This is sufficiently nearly correct for all practical purposes, and quite correct when dealing with mean values, for, where a slight advantage may be gained from the synchronisation of the pulsations at one speed, there will be a nearly equal loss at other speeds when the pulsations are out of phase.

The first point to take into consideration is the temperature of the working fluid. In the petrol engine we have a distinct advantage as compared with other engines because we can make use of the latent heat of evaporation of the fuel to lower the temperature of the working fluid. By this means we can reduce the temperature to as low as 7 deg. C. or 280 deg. C. absolute, this being about the minimum temperature at which the fuel will remain in the form of vapour. In practice, in order to prevent precipitation, or local freezing, it is generally necessary to heat the incoming charge to a somewhat higher temperature, but at the present moment we are considering limiting values only.

If the temperature of the working fluid in the induction pipe be taken as 280 deg. C. absolute, then, after passing through the inlet valve and coming into contact with the hot cylinder walls, it will be heated through a further 50 deg. C., or thereabouts, bringing the temperature up to 57 deg. C., or 330 deg. C. absolute. Now this may be taken as the minimum temperature of the incoming charge after its entry into the cylinder, but before mixing with the exhaust products. The density of the fluid at this temperature (neglecting the effect of the small percentage of petrol vapour) will be in proportion to its absolute temperature $= \frac{273}{330} = 0{\cdot}827$, hence 82·7 per cent. is the absolute volumetric efficiency in terms of standard pressure and temperature, and is the extreme limiting figure assuming :—

1. That the residual exhaust gases are at atmospheric pressure.
2. That the inlet valves and pipework offer no resistance, so that the cylinder is filled up to atmospheric pressure at the end of the suction stroke.

The temperature of the residual exhaust products after expansion, and the subsequent drop to atmospheric pressure, can be calculated with tolerable accuracy from

light spring diagrams; it is not susceptible of any great variation on full load, but depends, of course, to some extent upon the ratio of expansion. Calculated in this manner we find that the final temperatures are :—

Compression ratio—	Deg. C. absolute.
4 : 1	1·100
5 : 1	1·070
6 : 1	1·050

The density of the exhaust gases may be taken as $\frac{273}{1.100}$, $\frac{273}{1.070}$ and $\frac{273}{1.050}$ or 0.248, 0.253 and 0·260 respectively, neglecting the slight change in specific volume, which so far as these calculations are concerned, is practically negligible.

In the case of the 4 : 1 compression ratio the volume of the clearance space is one-third of the swept volume; it will be assumed that both the clearance space and the swept volume are full of gases at atmospheric pressure. The cylinder, therefore, contains 25 per cent. by volume of exhaust gases at an absolute temperature of 1·100 deg. C. and of density 0·248; and 75 per cent. of fresh charge at an absolute temperature of 330 deg. C. and of density 0·827. The proportion by weight is $25 \times 0{\cdot}248 = 6{\cdot}2$ of exhaust products, and $75 \times 0{\cdot}827 = 62$ of fresh charge, the mean temperature is, therefore :—

$$\frac{(6.2 \times 1.100) + (62 \times 330)}{6.2 + 62} = \frac{6.820 + 20.460}{68.2}$$

= 400 deg. C. absolute or 127 deg. C.

A little consideration will show that although the residual exhaust products impart heat to, and therefore expand the incoming charge as it enters the cylinder, they themselves must lose the same amount of heat and therefore contract to an extent which exactly counterbalances. This will apply equally, whatever compression ratio is employed. Similarly for a 5 : 1 compression ratio the final suction temperature will be 388 deg. C. absolute or 113 deg. C., and for a 6 : 1 ratio it will be 377 deg. C. or 104 deg. C. As a check on these figures for this actual suction temperature at the commencement of the compression stroke, the author would quote the following published tests made in order to ascertain the suction temperatures; two of these results were obtained by direct pyrometer readings, and one by separate measurements of the exhaust temperature, the inlet temperatures and the volumetric efficiency; the figures obtained were :—

Type of Engine.	Compression Ratio.	Suction Temperature, Absolute.	Authority.	Method of Determination.
		deg. C.		
Gas engine	4·6 : 1	398	Prof. Dalby ..	Pyrometer
Mercedes petrol	4·7 : 1	393	"Der Oelmotor"	"
Gas engine	6·3 : 1	375	Prof. Hopkinson	Deduction

These results are in very fair agreement with the calculated figures just arrived at. The importance of keeping the suction temperature as low as possible consistent with the requirements of carburation cannot be over-estimated, for it is the chief determining factor both as to the compression ratio which may be employed and the volumetric efficiency. The importance also of obtaining the highest possible orifice coefficient for the valve opening is one that is not always properly appreciated. It has already been emphasised that the most desirable condition to aim at is that in which the gases shall enter the cylinder at the highest possible velocity in order to ensure sufficient turbulence, and at the same time that the valves shall offer the least possible resistance. It is of no advantage to fit very large valves if their accommodation results either in reducing their orifice coefficient or in distorting the combustion chamber to any serious extent. Again, the position of the valve in the combustion chamber is a matter of primary importance. If the valve be placed in a side pocket as is quite common practice, the gases after passing through the valve port will be diverted almost immediately on entering the cylinders. This will result in the setting up of eddy currents with consequent loss of turbulence and loss of nozzle coefficient. It is now fully recognised that engines with valves fitted in the head of the cylinder in such a position that the flow of gas is not obstructed after passing the valve port, show a higher volumetric efficiency and a considerably higher thermal efficiency than those in which the valves are fitted in side pockets. The higher volumetric efficiency is to be accounted for by the freer entry; and the higher thermal efficiency, in part by the greater turbulence set up and in part by the reduction of cooling surface exposed to the gases when the valves are fitted in this position. Generally speaking, the part played by turbulence in controlling the thermal efficiency is underestimated, while that played by loss of heat to the cylinder walls during combustion and expansion is over-estimated.

In Fig. 8 page 620 *ante*, curves are shown giving (1) the theoretical limiting volumetric efficiency, and (2) and (3) the mean of a number of tests, (2) with valves fitted in side pockets, and (3) with valves in the cylinder head based in all cases on the mean gas velocity through the valves and assuming, in all cases, that the pipework is short and of large diameter. The actual volumetric efficiency, however, depends also of course upon the valve timing and, above all, upon the relation between the area of port opening immediately before the end of the suction stroke and the point at which the valve is closed, *i.e.*, upon the rapidity of the cut-off at the end of the suction stroke. It is upon the problem of obtaining the most rapid cut-off possible at this point that attention should be concentrated when designing the valve gear The rapidity with which the inlet valve can be made to close depends of course upon the strength of spring available, and the weight of the valve and its gear. The strength of spring is usually governed by mechanical consideration such as the space available on the one hand, and the tendency to failure due to periodic vibration on the other. It is necessary, therefore, to concentrate upon reducing the weight of the valve and its gear. Now a valve, unlike most other portions of an engine, is machined all over and is therefore unlimited as regards minimum thickness with the result that it obeys the dimensional theory and its weight varies as the cube of its diameter. It follows, therefore, that the weight per square inch of valve area will increase rapidly with increase of size, and the strength of spring cannot be increased in proportion. In order, therefore, to obtain the rapid closing which is so essential it becomes desirable in large high-speed engines to use multiple inlet valves after a certain size has been reached and, at about the same time, it becomes advisable to employ multiple exhaust valves not so much on the score of rapidity of operation as upon temperature considerations.

In case of petrol engines, however, it is necessary to consider also the effect of the carburettor upon the volumetric efficiency. The ordinary spray carburettor which is now almost universally employed, depends upon the velocity of the air past the petrol jet to pulverise the fuel, the subsequent vaporisation taking place partly in the carburettor and induction pipe and partly in the

Fig. 29.

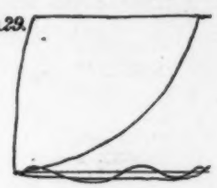


Fig. 30.

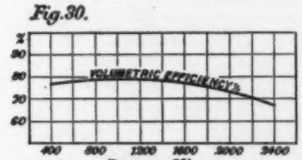
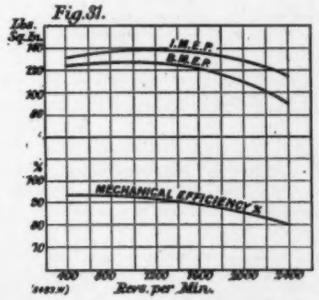


Fig. 31.



cylinder. Now it is not only necessary to employ a local high velocity in order to pulverise the fuel as finely as possible, but also to maintain a fairly high velocity throughout the induction pipe in order to prevent the finely-divided particles of fuel from precipitating on the walls of the pipe. To the resistance offered by the valves we have, therefore, to add that due to the carburettor and induction piping. In order to obtain the necessary degree of pulverisation in the carburettor a minimum velocity of about 250 ft. per second is required past the jet. This velocity can be obtained, however, by the use of a *vena contracta* without entailing anything like the resistance which the same velocity through the inlet valve would cause. With a well-designed choke tube the orifice coefficient should be at least 90 per cent., and the static head required to produce a velocity of 250 ft. per second will be about 0·6 lb. per square inch. This represents the mean resistance throughout the stroke; towards the end of the stroke the velocity naturally falls, and part at least of the kinetic energy is converted into static pressure, which in some cases nearly compensates for the resistance.

With regard to the exhaust piping, unless a very badly designed silencer be employed there should be little or no final back pressure. During the exhaust stroke the gases in the exhaust pipe are in a state of violent pulsation, as shown by the optical indicator diagram, Fig. 29, taken from a very high-speed engine, and with a light spring of 20 lb. = 1 in. These pulsations have a constant periodicity depending upon the length of the pipe; it follows, therefore, that the final pressure when the exhaust valve closes may be above or below atmospheric pressure, depending upon the speed of the engine. In taking the average exhaust terminal pressure as just atmospheric we are not assuming an impossible condition of affairs.

It is well to consider the possibilities of increasing the volumetric efficiency :—

(*a*) By utilising the kinetic energy of the gases in the exhaust pipe to scavenge out the clearance space, thus replacing the exhaust products with fresh charge.

(*b*) By utilising the energy of the gases in the induction pipe to supercharge the cylinder.

(*c*) By suitable adjustment of the length of the exhaust pipes and the overlapping of the inlet and exhaust valves, so that both are open near the end of the stroke, it is possible to produce a scavenging action at certain critical speeds, but in this case a considerable proportion of the incoming charge will pass unburnt down the exhaust pipe, and especially is this the case when the inlet and exhaust valves are close to one another. The gain in mean pressure is trifling compared with the loss of efficiency, and this method must be regarded as quite inadmissible in an aero-engine, for example, in which economy of fuel is one of the primary considerations, but it is worth taking into consideration in the case of engines for racing cars, &c.

(*b*) Supercharging by the induction pipe is very much more difficult to obtain for the following reasons :—

1. There is no initial high pressure to set up a high velocity and break down the existing pulsations in the pipe.

2. The induction pipe cannot usually be of great length, hence the periodicity of the pulsations is extremely rapid.

3. Neither the weight of the gas present in the relatively short pipe, nor its velocity is sufficient to produce any appreciable static pressure.

4. Owing to the high periodicity of the pulsations in the induction pipe, a very slight change in speed will throw the engine out of phase and produce an opposite effect.

5. If the induction pipe be small, giving high velocity, the static pressure produced does not compensate for the wire-drawing that the small pipe involves, and alternately, if the pipe be very large and the velocity low, the static pressure is small.

6. In a petrol engine violent pulsations and reversals must be avoided as far as possible, since they tend to precipitate the finely-divided particles of petrol which are held in suspension only by the velocity of the air.

APPENDIX III.

Detonation or "Pinking."

The phenomena of detonation or "pinking" do not appear to have received the degree of investigation that they are entitled to, in view of the fact that it is detonation rather than actual pre-ignition which limits the compression ratio and therefore both the power and efficiency of the petrol or paraffin engine. In the absence of more detailed investigation it is possible to do little more than theorise upon the subject, but the sequence of events appears to be as follows :—

With a compression ratio of 5 : 1, an initial pressure of 14·5 lb. per square inch absolute and an initial temperature of 388 deg. C. absolute, the working fluid at the end of the compression stroke is raised to a pressure of 123 lb. per square inch absolute and to a temperature of 652 deg. C. absolute, taking the value of the index γ for the compression stroke as 1·32, which appears to be about correct for an air-petrol mixture. Now this temperature of 652 deg. C. absolute or 379 deg. C. is very considerably below the self-ignition point of the fuel (the actual self-ignition temperature of air-petrol mixtures under compression has not yet been investigated, but although it appears certain that it decreases with compression it is equally certain that it is very considerably higher than 379 deg. C. On igniting the mixture combustion at first takes place in the usual manner, that is to say in waves spreading radially from the point of ignition. The rate at which these waves travel depends upon (*a*) the degree of turbulence of the working fluid at the moment of ignition, and (*b*) the actual pressure of compression. Neglecting for the moment the question of turbulence, it is obvious that the rapid rise of pressure due to the inflammation of the first portion of the charge will result in compression of the remaining portion. This portion will be compressed adiabatically and will also receive heat by radiation from the burning portion. Consequently its temperature will rise rapidly until it attains the self-ignition temperature of the fuel; and when this point is reached the remaining portion of the working fluid will ignite practically instantaneously throughout its whole bulk, resulting in a rapid rise of pressure, so rapid indeed as to cause the cylinder walls to vibrate in exactly the same manner as though they had been struck by a hammer. If this theory is accepted, and there appears to be abundant evidence in support of it, it follows that detonation will occur when the rate of the normal inflammation is sufficient to raise the temperature of the unburnt charge by compression above its ignition temperature and before it can be ignited by the normal spread of inflammation. It depends therefore upon :—

1. The normal rate of burning.

2. The proximity of the temperature of the more distant portion of the working fluid to its ignition temperature.

3. The temperature of the wall against which the more distant portion is compressed, *i.e.*, it will occur more readily if the charge is ignited on the opposite side to the exhaust valve against which the residual portion of the charge will be compressed.

Of these three considerations the first is by far the most important, and since the rate of propagation of the flame is dependent upon pressure it is clear that this, rather than temperature, is the chief governing condition. The author has experimented in this direction by carrying out the compression in two stages with effective intercooling between the stages, thus ensuring a very low

compression temperature: but even under these conditions detonation occurred when the final compression pressure was only 130 lb. per square inch absolute, although the final compression temperature was known to be not more than 280 deg. C.

The effect of turbulence is apparently twofold. On the one hand it increases the normal rate of flame propagation, and may therefore be expected to increase the tendency to detonate, but on the other hand by stirring up the contents of the combustion chamber it prevents the isolation of any unburnt portion of the charge. On the whole, turbulence appears to diminish rather than increase the tendency to detonate. Experience has shown that, as might be expected, both the shape of the combustion chamber and the position of the igniter have a very considerable bearing on the tendency of detonate. If the combustion chamber is compact and symmetrical, detonation is less liable to occur, presumably for the simple reason that there is less liability of any portion of the charge being isolated and compressed by the spread of inflammation.

APPENDIX IV.

PERFORMANCE OF HIGH-SPEED ENGINES.

In the light of present knowledge, the performance which may be expected from any normal design of engine, both as regards power and fuel consumption can be predicted with a very fair degree of accuracy using the formulæ and curves given previously for volumetric efficiency, piston friction and pumping losses. It is interesting to take one example and examine it in this way. We will take an engine having cylinders of 7·25-in. bore and 8·50-in. stroke, and consider the possible performance of one cylinder over a range of speed of from 400 r.p.m. up to 2,400 r.p.m., assuming for the time being that the mechanical construction were such as to render this latter speed possible. The leading dimensions of the engine will be taken to be as follows:—

Bore	7·25 in.
Stroke	8·50 in.
Area of piston	41·3 sq. in.
Swept volume of cylinder ...	351 sq. in.
Weight of reciprocating mass ...	11·35 lb.
Weight of rotating mass	8·00 lb.
Number of valves	4 (2 inlet and 2 exhaust).
Diameter of valve ports	2·5 in.
Lift of valves	0·65 in.
Effective area through valves ...	9·8 sq. in.
Ratio piston area to effective inlet port area...	3·94 : 1.
Diameter of crank-pin	3·25 in.
Width of crank-pin	3·75 in.
Projected area of bearing surface	11·37 sq. in.
Ratio piston area to projected area	3·63 : 1.

We will begin by assuming that the highest compression ratio we can safely use is 5 : 1. This will be just possible, provided that every part of the combustion chamber and particularly the surroundings of the exhaust valves and sparking plugs are well cooled by water in sufficiently rapid circulation to break away any steam bubbles that may be formed.

For a compression ratio of 5 : 1 the air standard efficiency is 47·5 per cent., and this forms the basis for our calculations. With a compact and symmetrical combustion chamber giving free circulation to the working fluid, without any shallow pockets, and with the minimum of cooling surface exposed to combustion, an efficiency relative to the air standard of 69 per cent. is attainable at high speeds. The relative efficiency will vary slightly; it will be lower at low speeds on account of the greater proportion of heat lost to the jackets; it will probably reach about 69 per cent. when the gas velocity is from 130 ft. to 180 ft. per second; *i.e.*, from 1,400 r.p.m. to 1,900 r.p.m., and will fall again slightly when the volumetric efficiency is seriously reduced by wire-drawing at the higher speeds.

Assuming for the present that the cylinder is completely filled with working fluid at atmospheric pressure the volumetric efficiency in terms of standard pressure and temperature will, as has been shown in Appendix III, be 82·7 per cent. With a mixture density of 98 British thermal units per cubic foot, and a thermal efficiency of 69 per cent. of the air standard, or 32·9 per cent., the indicated mean pressure would be

$$\frac{82.7}{100} \times \frac{98 \times 778}{144} \times \frac{32.8}{100} = 143 \text{ lb. per sq. inch.}$$

This is assuming the highest possible volumetric efficiency which is generally unobtainable, and is also incompatible with the other equally important condition of turbulence. In Fig. 8 is shown a curve (A) giving the highest volumetric efficiency attainable in terms of gas velocity through the valves, assuming the ideal valve setting for each speed. In Fig. 30 is shown the volumetric efficiency which should be obtainable in the engine now under discussion, in which the valves are the largest that can be used consistent with retaining a compact and symmetrical combustion chamber. It will be observed that the volumetric efficiency falls away slightly at speeds below 800 r.p.m. This is to be accounted for by the fact that the valves are assumed to be set to give the highest volumetric efficiencies at the higher speeds and that, in consequence, the inlet valves are held open too late at the lower speeds with the result that a small portion of the charge is rejected through them. If, now, instead of taking the volumetric efficiency as 82·7 per cent. we take it according to Fig. 30, and work out the same calculation for mean pressure, we find that the indicated mean pressure is as shown in Fig. 31. This curve is calculated allowing for the slight variation in the realitive efficiency referred to above.

Having obtained the indicated mean pressure over the full range of speed, it now remains to find the brake mean pressure by ascertaining the probably mechanical losses in terms of mean pressure, and deducting them from the indicated pressure. The loss due to piston friction may be found with a fair degree of accuracy from the empirical formula given on page 590 *ante*. The loss due to fluid pumping may be found from the curve in Fig. 4, 590 *ante*, and that due to bearings and auxiliaries, which in this case is taken to include a centrifugal water-circulating pump whose resistance will rise rapidly with increase of speed, may be estimated at the equivalent of 0·8 lb. mean pressure at 400 r.p.m., rising to 2·8 lb. mean pressure at 2,400 r.p.m. The three sources of loss referred to above are shown plotted in Fig. 32, from which it will be observed that the total friction rises to the equivalent of about 23 lb. per square inch at 2,400 r.p.m. Allowing for these losses the brake mean pressure and the mechanical efficiency will be as shown in Fig. 31. Fig. 33 shows the indicated and

Fig. 32.

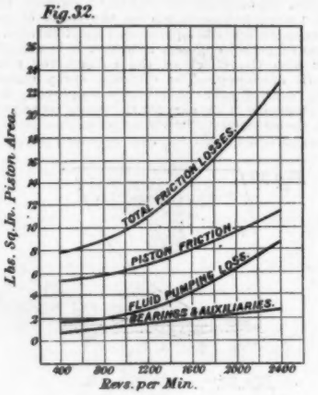
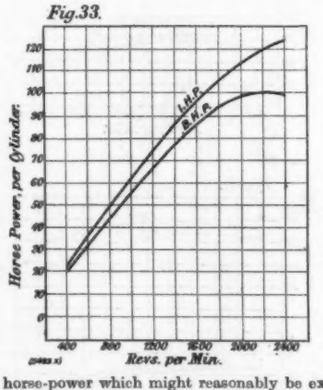


Fig. 33.



brake horse-power which might reasonably be expected from a cylinder of these dimensions. It will be observed that the maximum brake horse-power attainable is 100 brake horse-power, and this would be obtained at a speed of 2,100 r.p.m. if nothing interfered to prevent it. In point of fact, two limiting conditions will arise which will prevent the attainment of this power:—

1. It will not be possible by ordinary means, at all events, to operate the valves at this high speed; probably the limiting speed imposed by the valve gear will be in the neighbourhood of 1,900 r.p.m., judging from the author's experience.

2. The heat flow from the bearings due to the combined velocity and mean loading will become greater than can be coped with, with the result that the bearing linings will run out.

The author has found that when the load factor composed of the mean loading in terms of pounds per square inch on the projected area of the bearing, multiplied by the rubbing velocity in feet per second, exceeds 18,000, the condition of the bearings becomes critical (this statement must appear very arbitrary, for much must clearly depend on the means of conducting away the heat and upon the lubrication, but it is assumed that the bearings are designed with a view to dissipating heat as rapidly as possible, though, of course, not water cooled, and that a copious supply of cool oil is maintained under pressure). The load factor for one bearing—the connecting rod big-end—is shown in Fig. 34, from which it will be observed that the danger zone is reached at 1,770 r.p.m., and the critical speed at 1,970 r.p.m.

The above figures deal with the power output and mechanical efficiency of this engine, and it now remains to deal with the fuel consumption. In arriving at the mean pressure a figure of 69 per cent. was taken for the relative efficiency. This is the relative efficiency based upon fuel actually burnt in the cylinder and not necessarily upon the fuel supplied to it. The relative efficiency based on the fuel supplied will be somewhat lower, because combustion is seldom quite complete, and also because a certain proportion of petrol will inevitably be deposited upon the walls of the inlet piping, and will enter the cylinder in gulps of liquid which will escape anything like complete combustion. With carefully designed pipework this proportion can be kept very small, and it will also depend upon speed, the higher the speed and therefore the higher the velocity of the gases in the inlet pipe the lower will be the loss from precipitation of the fuel. The relation between the efficiency as shown by the actual fuel consumption, and that shown

Fig. 34.

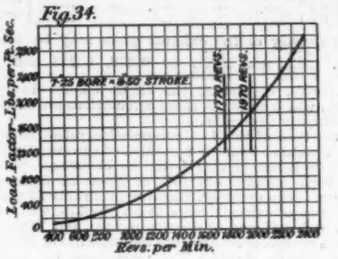
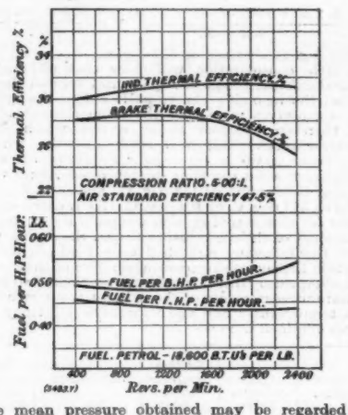


Fig. 35.


Thermal Efficiency %
IND. THERMAL EFFICIENCY %
BRAKE THERMAL EFFICIENCY %
COMPRESSION RATIO. 5·00 : 1.
AIR STANDARD EFFICIENCY 47·5%
Fuel per H.P. Hour. Lb.
FUEL PER B.H.P. PER HOUR.
FUEL PER I.H.P. PER HOUR.
FUEL. PETROL – 18,600 B.T.Us PER LB.
Revs. per Min.

by the mean pressure obtained may be regarded as representing the carburettor efficiency, and this may be taken as ranging, under favourable conditions, from about 95 per cent. at the lowest speed to 97 per cent. at the highest. If allowance be made for the carburettor efficiency the indicated thermal efficiency will be as shown in Fig. 35. This figure shows also the brake thermal efficiency and the fuel consumption in terms of pounds per horse-power relating to both the indicated and brake horse-power.

ACETYLENE AND METALS.—Though acetylene is apt to decompose and to explode when heated it can under certain conditions be heated to 800 deg. C. and higher for an hour before any serious decomposition and deposition of carbon occurs. Professor W. R Hodgkinson (Journal of the Society of Chemical Industry, March 30, 1918), passed acetylene gas, alone or diluted with nitrogen, coal-gas, &c., at a moderate speed through glass or silica tubes, and found that silica favoured decomposition less than glass; the heating could sometimes be continued for an hour. Various metals placed in the stream of gas had no visible action on the gas, and any carbon deposited upon them did not affect the metals though they were heated up to their melting points; the carbon afterwards burnt off without leaving any residue. Such metals were cadmium, zinc, lead, tin, aluminium and copper; Professor Hodgkinson did not draw attention to the behaviour of copper. Iron, nickel, cobalt and, further, to a lesser extent, manganese, tungsten, platinum and palladium, on the other hand, reacted with the gas, and the carbon deposited entered into combination. Small pieces or wires of the metal began to glow. Iron retained its strength under these conditions, being superficially carburised; nickel and cobalt became quite brittle and pitted, and these effects became noticeable already at the relatively low temperature of 200 deg. C. The most striking observation was, however, that the metal also entered by extrusion or vaporisation into the layer of soot on it, especially in the case of nickel, in the soot of which up to 15 per cent. of nickel were found. The carburisation by acetylene of iron was very rapid at 800 deg. C. and reached its maximum just below 1,000 deg. C. When the acetylene was mixed with ammonia gas, the carburisation was more rapid, less carbon was deposited, and the flame burnt smokeless; this suggested the formation of nitrides, and iron heated in ammonia gas alone turned into Fe_3N, which, on further heating in acetylene, became carburised, losing its nitrogen, but remaining brittle. Amines (aniline &c.) proved to be rapid carburisers of iron, and many benzene compounds behaved like acetylene, depositing soot, especially on nickel. The experiments may explain as was pointed out during the discussion, why iron burners, even when chilled, will not answer for acetylene, and why tar and the soot deposited from coal-gas always contain iron. Professor Hodgkinson kept oxygen out of his tube, so that carbon monoxide could not be present; he, however, noticed the presence of cyanogen in the gases from his tubes.